TRANSLATOR'S VERIFICATION

I hereby declare and state that I am knowledgeable of each of the Japanese and English languages and that I made and reviewed the attached translation of the certified copy of Japanese Patent Application No. 2002-364493, filed on December 16, 2002 from the Japanese language into the English language, and that I believe my attached translation to be accurate, true and correct to the best of my knowledge and ability.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of this application or any patent issued thereon.

Date: August 1, 2007

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[TITLE OF THE DOCUMENT] Specification

[TITLE OF THE INVENTION] INFORMATION-RECORDING METHOD AND INFORMATION-RECORDING MEDIUM

[CLAIMS]

[Claim 1] An information-recording method for recording information on an information-recording medium by scanning a laser beam at a linear velocity in a predetermined range relative to the information-recording medium and changing a state of a portion, of the information-recording medium, onto which the laser beam is irradiated to record the information,

characterized in that the information is recorded by a laser power of the laser beam with a pulse sequence including pulses which are modulated between at least a first power level Ph, a second power level Pl lower than the first power level, and a third power level Pm controlled between the first power level Ph and the second power level Pl;

the pulse sequence includes a plurality of pulses which are modulated at least by the first power level Ph and the third power level Pm; and

the third power level Pm is changed in response to the linear velocity.

[Claim 2] The information-recording method according to claim 1, characterized in that the third power

level Pm is increased in proportion to the linear velocity.

[Claim 3] An information-recording method for recording information on an information-recording medium by scanning a laser beam at a linear velocity in a predetermined range relative to the information-recording medium and changing a state of a portion, of the information-recording medium, onto which the laser beam is irradiated to record the information,

characterized in that the information is recorded by a laser power of the laser beam with a pulse sequence including pulses which are modulated between at least a first power level Ph, a second power level P1 lower than the first power level, and a third power level Pm controlled between the first power level Ph and the second power level Pl;

the pulse sequence includes a plurality of pulses which are modulated at least by the first power level Ph and the third power level Pm; and

a ratio Pm/Ph of the third power level Pm with respect to the first power level Ph is changed in response to the linear velocity.

[Claim 4] The information-recording method according to claim 3, characterized in that the ratio Pm/Ph of the third power level Pm with respect to the first power level Ph is increased in proportion to the linear velocity

[Claim 5] An information-recording method for recording information on an information-recording medium by scanning a laser beam at a linear velocity in a predetermined range relative to the information-recording medium and changing a state of a portion, of the information-recording medium, onto which the laser beam is irradiated to record the information,

characterized in that the information is recorded by a laser power of the laser beam with a pulse sequence including pulses which are modulated between at least a first power level Ph, a second power level P1 lower than the first power level, and a third power level Pm controlled between the first power level Ph and the second power level Pl;

the pulse sequence includes a plurality of pulses which are modulated at least by the first power level Ph and the third power level Pm; and

a relative ratio (Pm-P1)/(Ph-P1) of a difference between the third power level Pm and the second power level P1 with respect to a difference between the first power level Ph and the second power level P1 is changed in response to the linear velocity.

[Claim 6] The information-recording method according to claim 5, characterized in that the relative ratio (Pm-P1)/(Ph-P1) of the difference between the third

power level Pm and the second power level Pl with respect to the difference between the first power level Ph and the second power level Pl is increased in proportion to the linear velocity.

[Claim 7] The information-recording method according to any one of claims 1 to 6, characterized in that a pulse width of a leading pulse or a tail pulse of the pulse sequence including the plurality of pulses is changed in response to the third power level Pm.

[Claim 8] The information-recording method according to claim 7, characterized in that the pulse width of the leading pulse or the tail pulse of the pulse sequence including the plurality of pulses is increased in proportion to the third power level Pm.

[Claim 9] The information-recording method according to any one of claims 1 to 6, characterized in that a pulse width of a leading pulse or a tail pulse of the pulse sequence including the plurality of pulses is changed in response to a ratio Pm/Ph of the third power level Pm with respect to the first power level Ph.

[Claim 10] The information-recording method according to claim 9, characterized in that the pulse width of the leading pulse or the tail pulse of the pulse sequence including the plurality of pulses is increased in proportion to the ratio Pm/Ph of the third power level Pm

with respect to the first power level Ph.

[Claim 11] The information-recording method according to any one of claims 1 to 6, characterized in that a pulse width of a leading pulse or a tail pulse of the pulse sequence including the plurality of pulses is changed in response to a relative ratio (Pm-P1)/(Ph-P1) of a difference between the third power level Pm and the second power level P1 with respect to a difference between the first power level Ph and the second power level P1.

[Claim 12] The information-recording method according to claim 11, characterized in that the pulse width of the leading pulse or the tail pulse of the pulse sequence including the plurality of pulses is increased in proportion to the relative ratio (Pm-P1)/(Ph-P1) of the difference between the third power level Pm and the second power level P1 with respect to the difference between the first power level Ph and the second power level P1.

[Claim 13] An information-recording medium on which information is recorded by scanning a laser beam at a linear velocity in a predetermined range relative to the information-recording medium and changing a state of a portion, of the information-recording medium, onto which the laser beam is irradiated to record the information,

wherein the information is recorded by a laser power of the laser beam with a pulse sequence including pulses

which are modulated between at least a first power level Ph, a second power level Pl lower than the first power level, and a third power level Pm controlled between the first power level Ph and the second power level Pl;

the pulse sequence includes a plurality of pulses which are modulated at least by the first power level Ph and the third power level Pm;

the third power level Pm is a value which is changed in response to the linear velocity; and

an information representing a ratio of the third power level Pm with respect to the first power level Ph and an information regarding the linear velocity are both recorded on the information-recording medium.

[Claim 14] The information-recording method according to claim 13, characterized in that the information representing the ratio of the third power Pm with respect to the first power level Ph is recorded corresponding to the information regarding the linear velocity.

[Claim 15] An information-recording medium on which information is recorded by scanning a laser beam at a linear velocity in a predetermined range relative to the information-recording medium and changing a state of a portion, of the information-recording medium, onto which the laser beam is irradiated to record the information,

characterized in that the information is recorded by a laser power of the laser beam with a pulse sequence including pulses which are modulated between at least a first power level Ph, a second power level Pl lower than the first power level, and a third power level Pm controlled between the first power level Ph and the second power level Pl;

the pulse sequence includes a plurality of pulses which are modulated at least by the first power level Ph and the third power level Pm;

the third power level Pm is a value which is changed in response to the linear velocity; and

an information representing a relative ratio (Pm-Pl)/(Ph-Pl) of a difference between the third power level Pm and the second power level Pl with respect to a difference between the first power level Ph and the second power level Pl and an information regarding the linear velocity are both recorded on the information-recording medium.

[Claim 16] The information-recording medium according to claim 15, characterized in that the information representing the relative ratio (Pm-Pl)/(Ph-Pl) of the difference between the third power level Pm and the second power level Pl with respect to the difference between the first power level Ph and the second power level Pl is recorded corresponding to the information regarding

the linear velocity.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD TO WHICH THE INVENTION BELONGS]

The present invention relates to a method for recording information on an information-recording medium capable of recording the information by irradiating a laser beam onto the information-recording medium, and the information-recording medium to be used therefor. In particular, the present invention relates to an information-recording method which makes it possible to secure the compatibility of recording between information-recording media and apparatuses in which the recording liner velocities and the rising times and falling times of laser powers are different from each other, and the information-recording media to be used therefor. Further, the present invention relates to an information-recording method which makes it possible to easily optimize laser powers for apparatuses having different recording linear velocities, and an information-recording medium to be used therefor.

[0002]

[CONVENTIONAL ART]

In recent years, the market of read-only optical disks including, for example, DVD-ROM and DVD-Video is expanded.

On the other hand, rewritable DVD's including, for example, DVD-RAM, DVD-RW, and DVD-+RW are introduced into the market, and the market thereof is expanding for backup media for computers and image-recording media with which VTR may be substituted. In these several years, the demand of the market has increased for the improvement in the access speed and the transfer rate of recordable DVD's.

[0003] The method for recording information on the optical disk includes the CLV (Constant Linear Velocity) system and the CAV (Constant Angular Velocity) system. The CLV system resides in such a control method that the number of revolutions of the optical disk, i.e., the relative velocity between the laser beam and the optical disk is constant. On the other hand, the CAV system resides in such a system that the angular velocity, which is used to rotate the optical disk, is made constant to control the rotation.

[0004] The CLV system has the following features. (1) The signal processing circuit can be extremely simplified, because the data transfer rate is always constant during the recording and reproduction. (2) When the laser beam is moved in the radial direction of the optical disk, it is necessary that the number of revolutions of the motor is controlled again depending on the radial position. Therefore, the access speed is greatly lowered.

[0005] The CAV system has the following features. (1) The signal processing circuit is large-sized, because the data transfer rate differs depending on the radial position during the recording and reproduction. (2) It is possible to effect the high speed access, because it is unnecessary that the number of revolutions of the motor is controlled again depending on the radial position when the laser beam is moved in the radial direction of the optical disk.

[0006] The phase-change recording system is adopted for recordable DVD media such as DVD-RAM and DVD-RW on which information is recordable and erasable. In the case of the phase-change recording system, the recording is basically performed such that pieces of information of "0" and "1" are allowed to correspond to the crystal and the amorphous. Recorded "0" and "1" can be detected by radiating the laser beam to the crystallized portion and the amorphous portion and effecting the reproduction based on the reflected light beam.

[0007] In order to bring about the amorphous state at a predetermined position, the heating is effected so that the temperature of the recording layer is not less than the melting point of the recording layer material by radiating a laser beam having a relatively high power. On the other hand, in order to bring about the crystalline state at a predetermined position, the heating is effected so that the

temperature of the recording layer is in the vicinity of the crystallization temperature of not more than the melting point of the recording layer material by radiating a laser beam having a relatively low power. By dosing so, it is possible to reversibly change the amorphous state and the crystalline state.

[0008] A phenomenon called "recrystallization" occurs in the phase-change recording, in which the crystal growth takes place from the outer edge of the melted area during the cooling process which occurs immediately after the heating of the recording layer material to the temperature of not less than the melting point by means of the laser beam, and the size of the recording mark is consequently decreased. In order to suppress the deterioration of the shape of the recording mark caused by the recrystallization, the following method is generally adopted as described, for example, in Japanese Patent Application Laid-open Nos. 62-259229 and 3-185629. That is, the recording power is not radiated in a direct current manner, but the power is once lowered after the radiation of the recording power so that the radiation is effected in a form of pulse sequence. The design or construction of the recording pulse sequence is referred to as "recording strategy".

[0009] The optimization of the recording power may be

explained as exemplified by a drive for DVD-RAM. That is, the data is subjected to the trial writing by using a value of the recording power written on the disk, and the recording power is finely adjusted so that the error rate in the trial writing data is minimized. Accordingly, the recording power is optimized.

[0010]

[Patent Document 1] Japanese Patent Application Laid-open No. 3-185629

[Patent Document 2] Japanese Patent Application Laid-open No. 62-259229

[0011]

[PROBLEM TO BE SOLVED BY THE INVENTION]

In the case of the rewritable information-recording medium such as the optical disk, it is extremely important to secure the compatibility or the interchangeability with respect to the information-recording apparatuses based on various standards and produced by various manufacturers. For example, the DVD-RAM medium may be exemplified as follows. A DVD-RAM drive, which is adapted to the x2 speed based on the CLV rotation control (data transfer rate: 22 Mbps, linear velocity: 8.2 m/s), is already present in the market. However, in order to satisfy the demand of the market for the improvement in the transfer rate and the access speed, it is considered that those dominantly used

in future may be drives adapted to CLV in which the recording linear velocity is enhanced and drives adapted to CAV. Therefore, it is extremely important and indispensable for the benefit of consumers to guarantee the compatibility of the recording between the drive adapted to CAV and the drive adapted to the x2 speed CLV in which the recording linear velocity and the transfer rate are different from each other.

[0012] However, it is necessary to increase the frequency of the recording signal as the recording linear velocity is increased and the data transfer rate is raised. When the laser beam is pulse-modulated and radiated as described above, the time width of each of the pulses for constructing the pulse sequence is extremely shortened. On the other hand, the laser light-emitting element requires a certain period of time from the application of the driving current to the arrival of the light emission intensity at the intensity corresponding to the concerning current value. Therefore, if the width of the pulse becomes shorter than the period of time which is required until the light emission intensity of the light-emitting element arrives at the intensity corresponding to the driving current value in order to enhance the transfer rate, the laser light emission corresponding to each pulse is attenuated before the arrival at the peak value. As a result, the energy per unit area, which is applied to the

recording medium by the laser power, is deviated from the optimum value. Further, the shape of the recording mark to be written on the recording medium is distorted, and it is consequently impossible to record and reproduce information correctly.

[0013] On the other hand, the period of time, in which the light emission intensity arrives at the intensity corresponding to the current value after the driving current for the light-emitting element is applied, greatly differs depending on the type of the light-emitting element carried on the information-recording apparatus even when the wavelength for the laser light-emitting element is identical. Therefore, even when the recording is performed in accordance with an identical strategy, the energy per unit area, which is applied to the recording, is deviated from the optimum value depending on the type of the light-emitting element. Further, the shape of the recording mark to be written on the recording medium is distorted, and it is consequently impossible to record and reproduce information correctly.

[0014] The setting of the power is extremely important when information is recorded on the recording medium as described above. However, the situation is varied in a complicated manner depending on the unsaturation phenomenon of the laser power due to the recording linear velocity as

well as on the difference in the rising time and the falling time of the laser power depending on the type of the light-emitting element. Therefore, it is not easy to establish or set the optimum power for the information-recording apparatus.

[0015] Therefore, a first object of the present invention is to solve the problems as described above and provide an information-recording method and an information-recording medium to be used therefor in which the optimum recording laser power can be established with ease in an information-recording apparatus when the linear velocity during the data recording and the data transfer rate are increased.

[0016] A second object of the present invention is to solve the problems as described above and provide an information-recording method and an information-recording medium to be used therefor in which the recording compatibility can be secured even between information-recording apparatuses which carry light-emitting elements having different rising times and different falling times of the laser powers.

[0017] A third object of the present invention is to solve the problems as described above and provide an information-recording method and an information-recording medium to be used therefor in which the optimum recording

laser power can be established with ease in an information-recording apparatus when the linear velocity during the data recording and the data transfer rate are increased, and the recording compatibility can be secured on condition that the influence is taken into account between information-recording apparatuses which carry light-emitting elements having different rising times and different falling times of the laser powers.

[0018]

[MEANS FOR SOLVING THE PROBLEM]

In order to solve the problems as described above, the inventors of the present invention propose a recording method in which the optimum recording power can be established with ease when the recording linear velocity is increased. Further, the inventors propose the following information-recording method and the following information-recording medium to be used therefor in order to secure the recording compatibility for information-recording apparatuses having different linear velocities of the recording and the information-recording medium to be used therefor, namely:

[0019] (1) The above problem can be solved by an information-recording method for recording information on an information-recording medium by scanning a laser beam at a linear velocity in a predetermined range relative to the

information-recording medium and changing a state of a portion, of the information-recording medium, onto which the laser beam is irradiated to record the information; wherein the information is recorded by a laser power of the laser beam with a pulse sequence including pulses which are modulated between at least a first power level Ph, a second power level Pl lower than the first power level, and a third power level Pm controlled between the first power level Ph and the second power level Pl; the pulse sequence includes a plurality of pulses which are modulated at least by the first power level Ph and the third power level Pm; and the third power level Pm is changed in response to the linear velocity.

[0020] By using the information-recording method as described above, the following can be realized. That is, in a conventional case, when the recording linear velocity is increased, the data transfer rate is raised, and the clock length of the recording data is shortened, then the unsaturation of the laser power occurs due to this. As a result of the unsaturation of the laser power, the energy of the laser power of the recording pulse, which exceeds the optimum value, is applied to the information-recording medium. On the other hand, in the information-recording method of the present invention, the energy of the laser power of the recording pulse can be maintained at the optimum value by changing the third power level Pm in

response to the data transfer rate or the clock length of the recording data. Accordingly, it is possible to secure the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each other.

[0021] (2) By using the information-recording method in which the third power level Pm is increased in proportion to the linear velocity, first, it is possible to secure the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each other. Further, in a conventional case, when the optimum values of the laser powers Ph, Pl, and Pm are determined, it is necessary to separately determine three optimum powers respectively so that the error rate is minimized by changing the laser power value to be originally used. However, in this method, the optimum value of the laser power Pm can be determined in proportion to the recording linear velocity. Therefore, the laser powers, for each of which the optimum value is determined by actually changing the value of the recording laser power, are decreased into two of Ph and Pl. Therefore, it is possible to easily establish the optimum recording powers.

[0022] (3) Further, there is provided an information-

recording method for recording information on an information-recording medium by scanning a laser beam at a linear velocity in a predetermined range relative to the information-recording medium and changing a state of a portion, of the information-recording medium, onto which the laser beam is irradiated to record the information, wherein the information is recorded by a laser power of the laser beam with a pulse sequence including pulses which are modulated between at least a first power level Ph, a second power level Pl lower than the first power level, and a third power level Pm controlled between the first power level Ph and the second power level Pl; the pulse sequence includes a plurality of pulses which are modulated at least by the first power level Ph and the third power level Pm; and a ratio Pm/Ph of the third power level Pm with respect to the first power level Ph is changed in response to the linear velocity. By using the information-recording method as described above, the following can be realized. That is, the unsaturation state of the laser is also changed depending on the magnitude of the first power level Ph to be modulated. Therefore, when the value of Pm/Ph is changed in response to the recording linear velocity, it is possible to enhance the effect of securing the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each

other, than in a case that the value of Pm is changed in response to the recording linear velocity as in the above-described (1).

[0023] (4) Further, by using the information-recording method in which the ratio Pm/Ph is increased in proportion to the linear velocity, it is possible to secure the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each other. Furthermore, in a conventional case, when the optimum values of the laser powers Ph, Pl, and Pm are determined, it is necessary to separately determine three optimum powers respectively so that the error rate is minimized by changing the laser power value to be originally used. However, in this method, the optimum value of the laser power Pm can be determined from the recording linear velocity and the value of Ph by using the value of the Pm/Ph. Therefore, the laser powers, for each of which the optimum value is determined by actually changing the value of the recording laser power, are decreased into two of Ph and Pl. Therefore, it is possible to establish the optimum recording power easily.

[0024] (5) Moreover, there is provided an information-recording method for recording information on an information-recording medium by scanning a laser beam at a

linear velocity in a predetermined range relative to the information-recording medium and changing a state of a portion, of the information-recording medium, onto which the laser beam is irradiated to record the information; wherein the information is recorded by a laser power of the laser beam with a pulse sequence including pulses which are modulated between at least a first power level Ph, a second power level Pl lower than the first power level, and a third power level Pm controlled between the first power level Ph and the second power level Pl; the pulse sequence includes a plurality of pulses which are modulated at least by the first power level Ph and the third power level Pm; and a relative ratio (Pm-Pl)/(Ph-Pl) of a difference between the third power level Pm and the second power level Pl with respect to a difference between the first power level Ph and the second power level Pl is changed in response to the linear velocity. By using the information-recording method as described above, the following can be realized. That is, when the value of the (Pm-Pl)/(Ph-Pl), which represents the unsaturation state of the laser power, is changed in response to the recording linear velocity, it is possible to enhance the effect of securing the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each other, than in a case that the value of Pm in the above-

described (1) is changed in response to the recording linear velocity and than in a case that the value of Pm/Ph in the above-described (2) is changed in response to the recording linear velocity.

[0025] (6) Further, by using the information-recording method characterized in that the (Pm-P1)/(Ph-P1) is increased in proportion to the linear velocity, it is possible to secure the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each other. Furthermore, in a conventional case, when the optimum values of the laser powers Ph, P1, and Pm are determined, it is necessary to separately determine three optimum powers respectively so that the error rate is minimized by changing the laser power value to be originally used. However, in this method, the optimum value of the laser power Pm can be determined from the recording linear velocity and the values of the Ph and P1 by using the value of (Pm-P1)/(Ph-P1). Therefore, the laser powers, for each of which the optimum value is determined by actually changing the value of the recording laser power, are decreased into two of Ph and P1. Therefore, it is possible to establish the optimum recording power more easily.

[0026] (7) Furthermore, in each of the above (1) to (6),

by using the information-recording method characterized in that a pulse width of a leading pulse or a tail pulse of the pulse sequence including the plurality of pulses is changed in response to the third power level Pm, the following can be realized. That is, by changing, in response to the Pm, the pulse width of the leading pulse or the tail pulse of the multi-pulse waveform of the optimum recording strategy, it is possible to mitigate the influence exerted due to the change in the pulse width of the leading pulse and the tail pulse which would be otherwise caused by the unsaturation phenomenon of the laser power. In this case, it is possible to secure the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each other, more assuredly than each of the above (1) to (6) cases.

[0027] (8) Further, in the case of (7), by using the information-recording method characterized in that the pulse width of the leading pulse or the tail pulse of the pulse sequence including the plurality of pulses is increased in proportion to the third power level Pm, the following can be realized. That is, after securing the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are

different from each other, it is possible to determine the pulse with of the leading or tail pulse in proportion to the Pm. Therefore, it is possible to simplify the step of optimizing the recording strategy. Consequently, the optimization of the recording power, which is performed by using the optimum strategy, can be also performed with ease.

[0028] (9) Further, in each of the above (1) to (6), by using the information-recording method characterized in that a pulse width of a leading pulse or a tail pulse of the pulse sequence including the plurality of pulses is changed in response to a ratio Pm/Ph of the third power level Pm with respect to the first power level Ph, the following can be realized. That is, when the pulse width of the leading or tail pulse is changed in response to the value of Pm/Ph, it is possible to enhance the effect of securing the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each other, than in a case of the above (7) that the pulse width of the leading or tail pulse is changed in response to the value of Pm.

[0029] (10) Further, in the above (9), by using the information-recording method characterized in that the pulse width of the leading pulse or the tail pulse of the

pulse sequence including the plurality of pulses is increased in proportion to the ratio Pm/Ph of the third power level Pm with respect to the first power level Ph, the following can be realized. That is, after securing the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each other, it is possible to determine the pulse with of the leading or tail pulse in proportion to the Pm/Ph. Therefore, it is possible to simplify the step of optimizing the recording strategy. Consequently, the optimization of the recording power, which is performed by using the optimum strategy, can be also performed with ease.

[0030] (11) Further, in each of the above (1) to (6), by using the information-recording method characterized in that a pulse width of a leading pulse or a tail pulse of the pulse sequence including the plurality of pulses is changed in response to a relative ratio (Pm-P1)/(Ph-P1) of a difference between the third power level Pm and the second power level P1 with respect to a difference between the first power level Ph and the second power level P1, the following can be realized. That is, when the pulse width of the leading pulse or the tail pulse is changed in response to the value of (Pm-P1)/(Ph-P1), which represents the unsaturation state of the laser power, it is possible

to enhance the effect of securing the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each other, than in a case of the above (7) that the pulse width of the leading or tail pulse is changed depending on the value of Pm, or than in a case of the above (10) that the pulse width of the leading or tail pulse is changed depending on the value of Pm/Ph.

[0031] (12) Further, in the above (11), by using the information-recording method characterized in that the pulse width of the leading pulse or the tail pulse of the pulse sequence including the plurality of pulses is increased in proportion to the relative ratio (Pm-Pl)/(Ph-Pl) of the difference between the third power level Pm and the second power level Pl with respect to the difference between the first power level Ph and the second power level Pl, the following can be realized. That is, after securing the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each other, it is possible to determine the pulse with of the leading or tail pulse in proportion to the (Pm-Pl)/(Ph-Pl). Therefore, it is possible to simplify the step of optimizing the recording strategy. Consequently, the optimization of the recording power,

which is performed by using the optimum strategy, can be also performed with ease.

[0032] (13) Further, there is provided an information-recording medium on which information is recorded by scanning a laser beam at a linear velocity in a predetermined range relative to the information-recording medium and changing a state of a portion, of the information-recording medium, onto which the laser beam is irradiated to record the information; wherein the information is recorded by a laser power of the laser beam with a pulse sequence including pulses which are modulated between at least a first power level Ph, a second power level Pl lower than the first power level, and a third power level Pm controlled between the first power level Ph and the second power level Pl; the pulse sequence includes a plurality of pulses which are modulated at least by the first power level Ph and the third power level Pm; the third power level Pm is a value which is changed in response to the linear velocity; and an information representing a ratio of the third power level Pm with respect to the first power level Ph and an information regarding the linear velocity are both recorded on the information-recording medium. When the information-recording medium is used, it is possible to easily perform the step of determining the optimum recording power on the basis of the information on the recording speed and the

information of the ratio of Pm with respect to Ph written on the information-recording medium, irrelevant to the information-recording apparatuses in which the recording linear velocity, the rising time and the falling time of the laser power are different from each other. Further, it is possible to realize the recording compatibility between the different information-recording apparatuses.

[0033] (14) Further in the above (13), by using the information-recording medium in which the information representing the ratio of the third power Pm with respect to the first power level Ph is recorded corresponding to the information regarding the linear velocity, it is possible to simplify the information regarding the information-recording medium than in the case of (13), and consequently it is possible to optimize the recording power more easily.

[0034] (15) Further, there is provided an information-recording medium on which information is recorded by scanning a laser beam at a linear velocity in a predetermined range relative to the information-recording medium and changing a state of a portion, of the information-recording medium, onto which the laser beam is irradiated to record the information; wherein the information is recorded by a laser power of the laser beam with a pulse sequence including pulses which are modulated

between at least a first power level Ph, a second power level Pl lower than the first power level, and a third power level Pm controlled between the first power level Ph and the second power level Pl; the pulse sequence includes a plurality of pulses which are modulated at least by the first power level Ph and the third power level Pm; the third power level Pm is a value which is changed in response to the linear velocity; and an information representing a relative ratio (Pm-Pl)/(Ph-Pl) of a difference between the third power level Pm and the second power level Pl with respect to a difference between the first power level Ph and the second power level Pl and an information regarding the linear velocity are both recorded on the information-recording medium. When the information-recording medium is used, the following can be realized. That is, when the information of a value of (Pm-Pl)/(Ph-Pl), which represents the unsaturation state of the laser power and the information regarding the recording linear velocity are both recorded on the information-recording medium, it is possible to enhance the effect of securing the recording compatibility in information-recording apparatuses in which the recording linear velocity and the rising time and the falling time of the laser power are different from each other, more than in a case of the above (13) in which the information of the ratio of Pm with respect to Ph written on the information-recording medium

and the information regarding the recording velocity are both recorded on the information-recording medium.

[0035] (16) Further in the above (15), by using the information-recording medium in which the information representing the relative ratio (Pm-P1)/(Ph-P1) of the difference between the third power level Pm and the second power level P1 with respect to the difference between the first power level Ph and the second power level P1 is recorded corresponding to the information regarding the linear velocity, it is possible to simplify the information regarding the information-recording medium than in the case of (15), and consequently it is possible to optimize the recording power more easily.

[0036]

[EMBODIMENT OF THE INVENTION]

A detailed explanation will be made below about results of simulation and results of experiments performed by the inventors of the present application.

The inventors simulated, under the following conditions, the phenomenon in which the recording pulse waveform is distorted as the recording linear velocity is increased and the data transfer rate is raised.

(1) The clock frequency of the pulse is proportional to the recording linear velocity and the data transfer rate. (2) The waveforms of the rising and the falling of

the laser power are approximately calculated by using cosine curves. (3) The laser power is calculated in proportion to the square root of the recording linear velocity. (4) The rising time Tr and the falling time Tf of the laser power are calculated in proportion to the modulation amplitude. (5) The optimum value of the recording power is calculated so that the integrated energy of the pulse applied to the recording film is equal to the reference on the basis of a case in which the rising time and the falling time of the laser power are zero.

[0037] Figs. 1 and 2 show results of investigation about rising and falling responses of the laser power in the information-recording and reproducing apparatus designed for an optical recording medium. Dotted lines shown in the drawings are cosine curves which collate the responses of the actual machine. Therefore, it is affirmed that the calculation of the rising and the falling of the laser power of this case is reasonable.

[0038] Fig. 3 schematically shows a laser pulse for explaining the rising time and the falling time of the laser power. In this calculation, the rising time Tr of the laser power is the period of time required for the increase up to 90 % of the peak value after arrival at 10 % of the peak value of the laser power. On the other hand, the falling time Tf of the laser power is the period of

time required for the decrease down to 10 % of the peak value after arrival at 90 % of the peak value of the laser power.

[0039] Next, an explanation will be made about results of actual calculation performed by means of simulation.

The following simulation is performed on the basis of Ph = 11.0 mW and Pl = 5.0 mW at a transfer rate of 22 Mbps, a linear velocity of 8.2 m/s, and a clock length of T = 17.13 ns in the case of the x2 speed recording on DVD-RAM. When the calculation is made for a case in which the recording speed is increased 5-fold and the linear velocity is 20.1 m/s, there are given a clock length of T = 6.85 ns, Ph = 17.4 mW, and Pl = 7.9 mW. On condition that Tr = Tf = 0.0 ns is given at the x5 speed, the recording pulse waveform is as shown in Fig. 4. With reference to Fig. 4, the integrated energy applied to the recording film is calculated from the area of the shaded portion.

[0040] Subsequently, when the calculation is made for a case in which Tr = Tf = 3 ns is given at the x5 speed, the recording pulse waveform is as shown in Fig. 5. As understood from Fig. 5, when the recording linear velocity is increased and the clock length is shortened, then the falling of the pulse, which must fall down to the Pl level in principle, arrives at only the Pm level due to the unsaturation of the laser power. As a result, the

integrated energy of the pulse applied to the recording film, which is calculated by the area of the shaded portion shown in Fig. 5, is relatively larger than that obtained in Fig. 4. Any obtained mark is different from the mark recorded with the recording pulse waveform shown in Fig. 4. The present inventors have found out the following fact. That is, in order to perform the recording to obtain the same mark as the mark having the recording pulse waveform shown in Fig. 4, it is necessary that the Ph level for the recording is set to be somewhat low beforehand while considering the unsaturation of the laser power so that the integrated energy is conformed.

[0041] Fig. 6 shows results of the determination, by means of the simulation while considering the unsaturation of the laser power as described above, of the values of Ph at each of which the integrated energy of the pulse of the laser power is equal to that obtained when Tr (= Tf) is 0.0 ns, when Tr (= Tf) is varied from 0.5 ns to 4.0 ns in the recording at the x2, x3, x4, x5, x6, x7, and x8 speeds. As appreciated from the results of simulation shown in Fig. 6, the recording can be performed at an identical power level of Ph within a range of Tr (= Tf) from 0.5 ns to 3.5 ns in the x2 speed recording. However, in the x5 speed recording, if Tr (= Tf) is larger than 1.5 ns, the unsaturation phenomenon of the laser power occurs. Therefore, in order to perform the recording with the same

integrated energy as that obtained when Tr (= Tf) is 0.0 ns, it is necessary that the recording is performed at a laser power lower than that used when Tr (= Tf) is 0.0 ns. In the case of the x8 speed recording, no saturation is caused even when Tr (= Tf) is 0.0 ns. The laser power level Ph also differs between when Tr (= Tf) is 1.0 ns and when Tr (= Tf) is 2.5 ns.

[0042] As described above, the optimum laser power level Ph differs when the rising time and the falling time of the laser power differ due to the unsaturation phenomenon of the laser power. Further, the faster the recording linear velocity is, the more conspicuous this tendency is. This causes a serious problem when it is intended to establish the recording compatibility between the recording media and the recording apparatuses in which the rising time and the falling time of the laser power and the recording linear velocity are different from each other.

[0043] Fig. 7 shows results of the determination, by means of the simulation, of the values of Pm at the values of Ph at each of which the integrated energy is equal to that obtained when Tr (= Tf) is 0.0 ns while considering the unsaturation of the laser power as described above, when Tr (= Tf) is varied from 0.5 ns to 3.5 ns in the recording at the x2, x3, x4, x5, x6, x7, and x8 speeds. The recording can be performed at a power level of Pm = P1

within a range of Tr (= Tf) from 0.5 ns to 4.0 ns in the x2 speed recording, because the unsaturation phenomenon of the laser power is not caused. However, when the recording speed is increased, the unsaturation phenomenon of the laser power occurs. Therefore, for example, in the case of the x8 speed recording, the value of the laser power Pm differs between when Tr (= Tf) is 1.0 ns and when Tr (= Tf) is 2.5 ns.

[0044] As described above, the optimum laser power level Ph as well as the optimum laser power level Pm differs when the rising time and the falling time of the laser power differ due to the unsaturation phenomenon of the laser power. Further, the faster the recording linear velocity is, the more conspicuous this tendency is. This causes a serious problem when it is intended to establish the recording compatibility between the recording media and the recording apparatuses in which the rising time and the falling time of the laser power and the recording linear velocity are different from each other.

[0045] Figs. 8 and 9 show results in which the recording speed is newly plotted on the horizontal axis for those shown in Figs. 6 and 7. The recording speed is represented by multiples of the x1 speed (data transfer rate: 11 Mbps, linear velocity: 4.1 m/sec). As shown in Figs. 8 and 9, the laser power levels Ph and Pm change nonlinearly with

respect to the recording speed even when the rising time and the falling time of the laser are identical. This tendency is conspicuous as the rising time and the falling time of the laser are increased. The laser powers Ph and Pm are changed nonlinearly with respect to the recording speed as described above, and hence it is necessary that the three powers, i.e., Ph, Pl, and Pm are changed respectively individually for every recording linear velocity so that the error rate is minimized when the optimum recording laser power is determined for the information-recording apparatus in which the recording linear velocity differs, resulting in any complicated procedure for the trial writing with the laser power. This causes a serious problem.

[0046] The present inventors propose the following method for solving the problems, i.e., the complicated step of determining the optimum laser power levels Ph, Pl, and Pm as well as the difficulty of establishment of the recording compatibility between recording apparatuses and recording media when the rising time and the falling time of the laser power and the linear velocity during the recording are different from each other due to the unsaturation phenomenon of the laser power as described above.

[0047] A factor [(Pm-Pl)/(Ph-Pl)] is assumed to

represent the unsaturation of the laser level. Fig. 10 shows results of the summarized way of the change of the unsaturation level when Tr (= Tf) is from 0.5 ns to 3.5 ns assuming that the horizontal axis represents the recording speed and the vertical axis represents [(Pm-P1)/(Ph-P1)] x 100 for the results shown in Figs. 6 and 7 described above. When Tr (= Tf) is 0.5 ns, the unsaturation phenomenon of the laser power is not caused during the recording at the x2 speed to the x8 speed. Therefore, the unsaturation level [(Pm-P1)/(Ph-P1)] x 100 is 0 %. However, when Tr (= Tf) is from 1.0 ns to 3.5 ns, the unsaturation level is nonlinearly changed. If this situation is left as it is, it is impossible to easily determine the unsaturation level, the power levels Ph and Pm at the respective Tr's (= Tf's) and the recording speeds.

[0048] However, as indicated by a thick line shown in Fig. 11, the relationship between [(Pm-P1)/(Ph-P1)] and the recording speed may be set beforehand so that the relationship is conveniently linear so as to exceed the unsaturation level to be generated. By doing so, the recording speed may be determined without being affected by the unsaturation phenomenon caused by the rising time and the falling time of the laser power. Accordingly, it is possible to determine the power levels Ph and Pm by using the value of [(Pm-P1)/(Ph-P1)]. Assuming that the relationship between [(Pm-P1)/(Ph-P1)] and the recording

speed is represented by the thick line shown in Fig. 11, there is given [(Pm-P1)/(Ph-P1)] = (recording speed) x (80/6) - (80/3) (%). In this case, the recording speed is represented by the multiples with respect to the x1 speed.

[0049] Figs. 12 and 13 show values of Ph and values of Pm determined so that the integrated energy is equal to that obtained when Tr (= Tf) is 0.0 ns, when Tr (= Tf) is changed from 0.5 ns to 3.5 ns in the recording at the x2, x3, x4, x5, x6, x7, and x8 speeds by using the relational expression between [(Pm-P1)/(Ph-P1)] and the recording speed described above.

[0050] The following fact is appreciated when Fig. 12 is compared with Fig. 6. That is, no variation arises in the power level Ph, which would be otherwise caused depending on Tr, Tf at the respective recording speeds when the certain relational expression is established between [(Pm-P1)/(Ph-P1)] and the recording speed so that the unsaturation level shown in Fig. 11 is exceeded as compared with the case in which the situation is affected by the unsaturation of the laser power as shown in Fig. 6.

[0051] Further, the following fact is appreciated when Fig. 13 is compared with Fig. 7. That is, no variation arises in the power level Pm, which would be otherwise caused depending on Tr, Tf at the respective recording speeds when the certain relational expression is

established between [(Pm-P1)/(Ph-P1)] and the recording speed so that the unsaturation level shown in Fig. 11 is exceeded as compared with the case in which the situation is affected by the unsaturation of the laser power as shown in Fig. 7.

[0052] According to the results shown in Figs. 12 and 13, the following fact is appreciated. That is, it is possible to bring about the recording compatibility between the information-recording apparatuses by establishing the certain relational expression between [(Pm-P1)/(Ph-P1)] and the recording speed, even when the rising time and the falling time of the laser power and the linear velocity during the recording differ, because the recording laser power levels Ph and Pm are constant on the basis of the linear velocity during the recording even when the rising time and the falling time of the laser power are different from each other.

[0053] Figs. 14 and 15 show results in which the recording speed is newly plotted on the horizontal axis for those shown in Figs. 12 and 13. The recording speed is represented by multiples of the x1 speed.

The following fact is appreciated when Fig. 14 is compared with Fig. 8. That is, the laser power Ph can be definitely determined from the recording speed without depending on the rising time and the falling time of the

laser when the certain relational expression is established between [(Pm-Pl)/(Ph-Pl)] and the recording speed so that the unsaturation level shown in Fig. 14 is exceeded as compared with the case in which the situation is affected by the unsaturation of the laser power as shown in Fig. 8.

[0054] The following fact is appreciated when Fig. 15 is compared with Fig. 9. That is, the laser power Pm can be definitely determined from the recording speed without depending on the rising time and the falling time of the laser when the certain relational expression is established between [(Pm-Pl)/(Ph-Pl)] and the recording speed so that the unsaturation level shown in Fig. 15 is exceeded as compared with the case in which the situation is affected by the unsaturation of the laser power as shown in Fig. 9.

[0055] According to the results shown in Figs. 14 and 15, the following fact is appreciated. That is, it is possible to definitely determine the optimum recording powers of Ph and Pm from the recording linear velocity by previously establishing the certain relational expression between [(Pm-Pl)/(Ph-Pl)] and the recording linear velocity even when the rising time and the falling time of the laser power and the linear velocity during the recording differ, because the recording laser power levels Ph and Pm can be definitely determined on the basis of the linear velocity during the recording even when the rising time and the

falling time of the laser power differ.

[0056] As described above, when the certain relationship is established between [(Pm-P1)/(Ph-P1)] and the recording linear velocity so as to exceed the unsaturation level generated within the ranges of the use of the rising time and the falling time of the laser power and the recording linear velocity, the laser power Pm can be derived from the certain relationship based on the recording linear velocity without considering the unsaturation phenomenon of the laser which would be otherwise caused by the rising time and the falling time of the laser power. In other words, the value of Pm can be determined by means of the calculation by determining the laser powers Ph and P1. Accordingly, in spite of the fact that the three values of Ph, P1, and Pm must be separately determined in principle as the optimum recording powers, the value of Pm is spontaneously determined when Ph and P1 are determined. Thus, it is easy to perform the step of determining the optimum recording laser power.

[0057] When this method is used for the recording apparatus or when this method is recorded beforehand as information on the recording medium, then it is easy to perform the step of determining the optimum recording power, and it is also possible to secure the compatibility of the recording between the apparatuses in which the

rising time and the falling time of the laser beam are different from each other.

[0058] Similarly, Fig. 16 shows results of the summarized way of the change of the unsaturation level when Tr (= Tf) is from 0.5 ns to 3.5 ns assuming that the horizontal axis represents the recording speed and the vertical axis represents Pm/Ph for the results shown in Figs. 5 and 6 described above. In the same manner as in the case shown in Fig. 11, when the relationship between Pm/Ph and the recording speed is linearly approximated in a convenient manner beforehand so that the unsaturation level to be generated is exceeded as shown by a thick line shown in Fig. 16, it is also possible to determine the value of Pm by using the value of Ph from the value of Pm/Ph by determining the recording speed without being affected by the unsaturation phenomenon which would be otherwise caused by the rising time and the falling time of the laser power.

[0059] Similar results are also obtained even when the ratio of Pm/Ph plotted on the vertical axis of Fig. 16 is normalized with a ratio Pmx2/Phx2 of Pm/Ph at a certain recording linear velocity, for example, in the x2 speed recording as shown in Fig. 17. That is, when the relationship between (Pm/Ph)/(Pmx2/Phx2) and the recording speed is linearly approximated in a convenient manner beforehand so that the unsaturation level to be generated

is exceeded as shown by a thick line shown in Fig. 17, it is also possible to determine the value of Pm by using the value of Ph from the value of Pm/Ph by determining the recording speed without being affected by the unsaturation phenomenon which would be otherwise caused by the rising time and the falling time of the laser power.

[0060] This simulation is illustrative of the case in which Tr/Tr = 1, i.e., Tr = Tf is given. However, even in the case of Tr/Tr < 1 or Tr/Tf > 1, the same or equivalent effect is obtained in the same manner as in the case of Tr/Tf = 1.0 irrelevant to the value of Tr/Tf by setting the certain relationship for the laser powers Ph, Pm, and P1 and the recording linear velocity in the same manner as in the case described above on condition that Tr/Tf is determined to be another value beforehand. When the certain relationship is established between the laser powers Ph, Pm, and P1 and the speed during the recording in the same manner as described above after determining the value of Tr/Tf approximately at the center of the assumed variation, it is possible to suppress and minimize the variation of the optimum value of the laser power which would be otherwise caused by the variation of the value of Tr/Tf.

[0061] Further, Examples of the present invention will be described, in which experiments were actually performed

on the basis of the results obtained by the simulation described above.

The following layers were formed by means of the sputtering process on a polycarbonate substrate with a radius of 120 mm and a thickness of 0.6 mm having a surface covered with concave/convex guide grooves with a groove depth of 65 nm and a track pitch of 1.2 μm based on the format of 4.7 GB DVD-RAM. That is, those successively formed as films were 100 nm of $ZnS-SiO_2$ as a first protective layer, 10 nm of GeCrN as a first interface layer, 10 nm of BiGeTe as a recording layer, 10 nm of GeCrN as a second interface layer, 50 nm of $ZnS-SiO_2$ as a second protective layer, 50 nm of GeCr as a heat absorption factor-correcting layer, and 80 nm of Al as a heat-diffusing layer to obtain an information-recording medium used for Examples.

[0062] The information-recording medium was subjected to the crystallization by using a laser initializing apparatus. When the recording and reproduction characteristics were investigated thereafter, an information-recording and reproducing apparatus for optical recording media as shown in Fig. 18 was used.

[0063] An explanation will be made below about the operation and the recording and reproduction process of the information-recording and reproducing apparatus for optical

recording media used in Examples of the present invention. At first, the information, which is supplied from the outside of the recording apparatus, is transmitted in units each composed of 8 bits to an 8-16 modulator 18-7. When the information is recorded on the information-recording medium 18-1, the apparatus uses a modulation system for converting 8-bit information into those of 16 bits, i.e., the so-called 8-16 modulation system. In this modulation system, the information is recorded with mark lengths of 3T to 14T allowed to correspond to the information of 8 bits. In the drawing, the 8-16 modulator 18-7 performs this modulation. T herein represents the clock length of the data during the information recording. In this embodiment, the clock length was 17.1 ns when the recording linear velocity was 8.2 m/s, and the clock length was 6.9 ns when the recording linear velocity was 20.5 m/s.

[0064] The digital signals of 3T to 14T, which are converted by the 8-16 modulator 18-7, are transferred to a recording waveform-generating circuit 18-5 to generate a multi-pulse recording waveform in which the pulse having the power at the first power level Ph as the high power has a width of about T/2, the laser is radiated at the second power level Pl or the third power level Pm between the first power level Ph and the second power level Pl having a width of about T/2 during the period of time of the radiation of the laser of Ph, and the laser is radiated at

Pm or the intermediate power level P1 between a series of pulses at the Ph level. In the recording waveform-generating circuit 18-5, the signals of 3T to 14T are allowed to alternately correspond to "0", "1", and "2" in a time series manner. The laser power at the power level of P1 is radiated in the case of "0", the laser power at the power level of Pm is radiated in the case of "1", and the laser power at the power level of Ph is radiated in the case of "2". During this procedure, the portion on the information-recording medium 18-1, which is radiated with the laser beam at the power level of P1, is changed to the crystal. The portion, which is radiated with a series of pulse sequence including pulses at the power level of Ph, is changed to the amorphous (mark portion). The recording waveform-generating circuit 18-5 has a multi-pulse waveform table corresponding to the system (adaptive recording waveform control) in which the width Tfp of the leading pulse and the width Tlp of the tail pulse of the multi-pulse waveform as shown in Fig. 19 are changed depending on the space lengths before and after the mark portion when the series of pulse sequence including the pulses at the power level of Ph for forming the mark portion is formed. Accordingly, the multi-pulse recording waveform is generated, which makes it possible to maximally exclude the influence of the thermal interference between the marks which would be otherwise caused between the marks.

[0065] The recording waveform, which is generated by the waveform-generating circuit 18-5, is transferred to a laser-driving circuit 18-6. The laser-driving circuit 18-6 allows a semiconductor laser contained in an optical head 18-3 to emit light. The semiconductor laser having a wavelength of 655 nm is used to produce a laser beam for recording the information for the optical head 18-3 carried on the information-recording and reproducing apparatus for optical recording media of this embodiment. The laser beam is focused on the recording layer of the information-recording medium 18-1 by using an objective lens having NA of 0.6 to perform the recording by radiating the laser beam of the laser corresponding to the recording waveform as described above.

[0066] The information-recording and reproducing apparatus for optical recording media of this embodiment is adapted to the system (so-called land-groove recording system) in which the information is recorded on both of the groove and the land (area between the grooves). The information-recording and reproducing apparatus for optical recording media of this embodiment includes an L/G servo circuit 18-8 which makes it possible to arbitrarily select the tracking for the land and the groove. The recorded information was reproduced by using the optical head 18-3 as well. The laser beam is radiated onto the recorded

marks, and the reflected light beam is detected from the marks and the portions other than the marks to obtain a reproduced signal. The amplitude of the reproduced signal is amplified by a preamplifier circuit 18-4, which is transferred to an 8-16 demodulator 18-9. The 8-16 demodulator 18-9 makes conversion into 8-bit information for every unit of 16 bits. As a result of the operation as described above, the reproduction from the recorded marks is completed. When the recording is performed on the optical information-recording medium 18-1 under the condition described above, then the mark length of the 3T mark as the shortest mark is about 0.42 μm, and the mark length of the 14T mark as the longest mark is about 1.96 μm.

[0067] When the jitter was evaluated, the following procedure was adopted. That is, a random pattern signal including 3T to 14T was recorded and reproduced, and a reproduced signal was subjected to the processes of waveform equivalence, binary conversion, and PLL (Phase Locked Loop) to measure the jitter.

[0068] In the embodiment of the present invention, an apparatus A and an apparatus B were used, in which only the characteristics of the optical head 18-3 and the laser-driving circuit 18-6 were different from each other in the recording and reproducing apparatus for optical recording

media described above. The values of the rising time Tr and the falling time Tf of the laser power are as follows in the apparatus A and the apparatus B. That is, Tr = 2.7 ns and Tf = 2.4 ns are given in the case of the apparatus A, and Tr = 1.1 ns and Tf = 0.9 ns are given in the case of the apparatus B. In this embodiment, Tr and Tf were measured in accordance with the following procedure. The laser beam was subjected to the voltage conversion by using a photoelectric power converter to make the display on an oscilloscope. The period of time, in which the output is raised from 10 % to 90 %, was regarded as Tr, and the period of time, in which the output is lowered from 90 % to 10 %, was regarded as Tf.

[0069] An explanation will be made below about the procedure in which the apparatuses for evaluating optical recording media having different Tr's and Tf's were used to record data while changing the construction (recording strategy) of the recording pulse sequence and the recording linear velocity, the data was reproduced while changing the reproducing linear velocity, and the value of the jitter was investigated during the data reproduction for the compatibility of the recording and reproduction between the apparatuses. In this embodiment, the x2 speed recording is performed while setting the recording linear velocity to 8.2 m/s, the clock length of the recording data to 17.1 ns, and the data transfer rate to 22 Mbps. Further, the x5

speed recording is performed while setting the recording linear velocity to 20.5 m/s, the clock length of the recording data to 6.9 ns, and the data transfer rate to 55 Mbps.

[0070] The jitter was measured as follows. That is, a random pattern was recorded ten times in an order from the inner circumference to the outer circumference on continuous five tracks, and the value of the jitter was measured while setting the reproducing laser power to 1.0 mW on the central track of the five tracks. In this embodiment, the following setting is made. That is, the recording linear velocity in the x5 speed recording is 20.5 m/s, the clock length is 6.9 ns, the target value of the jitter when the data transfer rate is 55 Mbps is not more than 8 %, and the upper limit value of the standard is not more than 9 %.

[0071]

[Comparative Example 1]

(Procedure 1-1)

At first, the width of the leading pulse and the width of the tail pulse of the multi-pulse waveform were optimized for the information-recording medium by means of the adaptive recording waveform control on the land so that the power levels of Pm and P1 were equal to one another under a condition of the linear velocity of 8.2 m/s with

the apparatus B in which the values of Tr and Tf were small. A prepared recording strategy Sb0 was used to record a random signal on the groove and the land with the optimum powers. The signal was reproduced at a linear velocity of 8.2 m/s to investigate the reproduction jitter on the groove and the land. The optimum recording powers were determined as follows. That is, the values of Ph and Pl were determined by changing the power respectively so that the jitter was minimized.

[0072]

(Procedure 1-2)

Subsequently, the optimum powers were determined on the groove and the land for the information-recording medium by using the recording strategy Sb0 under a condition of the linear velocity of 8.2 m/s with the apparatus A in which Tr and Tf are large. After that, a random signal was recorded. The signal was reproduced at a linear velocity of 8.2 m/s to investigate the reproduction jitter on the groove and the land. The optimum recording powers were determined by changing the values of Ph and Pl respectively so that the jitter was minimized.

[0073]

[Comparative Example 2]

(Procedure 2-1)

In this case, the width of the leading pulse and the

width of the tail pulse of the multi-pulse waveform were optimized for the information-recording medium by means of the adaptive recording waveform control on the land so that the power levels of Pm and P1 were equal to one another under a condition of the linear velocity of 20.5 m/s with the apparatus B. A prepared recording strategy Sb1 was used to record a random signal on the groove and the land with the optimum powers. The signal was reproduced at a linear velocity of 20.5 m/s to investigate the reproduction jitter on the groove and the land. The optimum recording powers were determined by changing the values of Ph and P1 respectively so that the jitter was minimized.

[0074]

(Procedure 2-2)

Subsequently, the optimum powers were determined on the groove and the land so that the power levels of Pm and P1 were equal to one another for the information-recording medium by using the recording strategy Sb1 under a condition of the linear velocity of 20.5 m/s with the apparatus A. After that, a random signal was recorded. The signal was reproduced at a linear velocity of 20.5 m/s to investigate the reproduction jitter on the groove and the land. The optimum recording powers were determined by changing the values of Ph and P1 respectively so that the jitter was minimized.

[0075]

[Example 1]

(Procedure 3-1)

Further, the width of the leading pulse and the width of the tail pulse of the multi-pulse waveform were optimized by means of the adaptive recording waveform control on the land so that Pm/Ph = 0.65 was satisfied with the apparatus B. A prepared recording strategy Sb2 was used to record a random signal on the groove and the land with the optimum powers. The signal was reproduced at a linear velocity of 20.5 m/s to investigate the reproduction jitter on the groove and the land. The optimum recording powers were determined by changing the values of Ph and P1 respectively so that the jitter was minimized. The value of Pm was determined from the determined value of Ph by using a relational expression of Pm = 0.65 * Ph.

[0076]

(Procedures 3-2, 3-3)

On the other hand, the signal recorded with the apparatus B was reproduced at linear velocities of 20.5 m/s and 8.2 m/s with the apparatus A to investigate the reproduction jitter on the groove and the land.

[0077]

(Procedure 3-4)

Subsequently, the optimum powers were determined on the groove and the land so that Pm/Ph = 0.65 was satisfied

for the information-recording medium by using the recording strategy Sb2 under a condition of the linear velocity of 20.5 m/s with the apparatus A. After that, a random signal was recorded. The signal was reproduced at a linear velocity of 20.5 m/s to investigate the reproduction jitter on the groove and the land. The optimum recording powers were determined by changing the values of Ph and Pl respectively so that the jitter was minimized. The value of Pm was determined from the determined value of Ph by using a relational expression of Pm = 0.65 * Ph.

[0078]

(Procedures 3-5, 3-6)

On the other hand, the signal recorded with the apparatus A was reproduced at linear velocities of 20.5 m/s and 8.2 m/s with the apparatus B to investigate the reproduction jitter on the groove and the land.

[0079]

[Example 2]

(Procedure 4-1)

Further, the width of the leading pulse and the width of the tail pulse of the multi-pulse waveform were optimized by means of the adaptive recording waveform control on the land so that Pm/Ph = 0.75 was satisfied with the apparatus B. A prepared recording strategy Sb3 was used to record a random signal on the groove and the land

with the optimum powers. The signal was reproduced at a linear velocity of 20.5 m/s to investigate the reproduction jitter on the groove and the land. The optimum recording powers were determined by changing the values of Ph and Pl respectively so that the jitter was minimized. The value of Pm was determined from the determined value of Ph by using a relational expression of Pm = 0.75 * Ph.

[0080]

(Procedures 4-2, 3-3)

On the other hand, the signal recorded with the apparatus B was reproduced at linear velocities of 20.5 m/s and 8.2 m/s with the apparatus A to investigate the reproduction jitter on the groove and the land.

[0081]

(Procedure 4-4)

Subsequently, the optimum powers were determined on the groove and the land so that Pm/Ph = 0.75 was satisfied for the information-recording medium by using the recording strategy Sb3 under a condition of the linear velocity of 20.5 m/s with the apparatus A. After that, a random signal was recorded. The signal was reproduced at a linear velocity of 20.5 m/s to investigate the reproduction jitter on the groove and the land. The optimum recording powers were determined by changing the values of Ph and Pl respectively so that the jitter was minimized. The value

of Pm was determined from the determined value of Ph by using a relational expression of Pm = 0.75 * Ph.

[0082]

(Procedures 4-5, 4-6)

On the other hand, the signal recorded with the apparatus A was reproduced at linear velocities of 20.5 m/s and 8.2 m/s with the apparatus B to investigate the reproduction jitter on the groove and the land.

[0083] As described above, the apparatuses for evaluating the optical information-recording medium, in which Tr and Tf were different from each other, were used to record the data while changing the construction of the recording pulse sequence (recording strategy) and the recording linear velocity. Further, the data was reproduced while changing the reproducing linear velocity to investigate the value of the jitter during the data reproduction in relation to the compatibility in the recording and reproduction between the apparatuses. Obtained results are summarized in Table 1. In Table 1, the unsaturation level is represented by the numerical value calculated by (Pm-Pl)/(Ph-Pl).

[0084]

Table 1-1

	Procedure	Recording strategy	Recording apparatus	Recording linear velocity (m/s)	Reproducing apparatus	Reproducing linear velocity (m/s)
Comp. Ex. 1	1-1	Sb0	B	8.2	B	8.2
	1-2	Sb0	A	8.2	A	8.2
Comp. Ex. 2	2-1	Sb1	B	20.5	B	20.5
	2-2	Sb1	A	20.5	A	20.5
Ex. 1	3-1	Sb2	B	20.5	B	20.5
	3-2	Sb2	B	20.5	A	20.5
	3-3	Sb2	B	20.5	A	8.2
	3-4	Sb2	A	20.5	A	20.5
	3-5	Sb2	A	20.5	B	20.5
	3-6	Sb2	A	20.5	B	8.2
Ex. 2	4-1	Sb3	B	20.5	B	20.5
	4-2	Sb3	B	20.5	A	20.5
	4-3	Sb3	B	20.5	A	8.2
	4-4	Sb3	A	20.5	A	20.5
	4-5	Sb3	A	20.5	B	20.5
	4-6	Sb3	A	20.5	B	8.2

Table 1-2

	Proce -dure	Groove /land	Ph (mW)	Pl (mW)	Pm (mW)	Pm/Ph	Unsatu-ration level	Jitter (%)
Comp. Ex. 1	1-1	Groove	10.2	4.2	4.2	0.41	0.00	8.5
		Land	10.5	4.4	4.4	0.42	0.00	8.2
	1-2	Groove	10.0	4.2	4.2	0.42	0.00	8.6
		Land	10.4	4.4	4.4	0.42	0.00	8.4
Comp. Ex. 2	2-1	Groove	14.7	6.4	6.4	0.44	0.00	7.7
		Land	15.1	6.5	6.5	0.43	0.00	7.4
	2-2	Groove	13.9	6.2	6.2	0.45	0.00	10.4
		Land	14.2	6.5	6.5	0.46	0.00	9.8
Ex. 1	3-1	Groove	11.8	6.2	7.7	0.65	0.27	7.6
		Land	12.4	6.5	8.1	0.65	0.27	7.3
	3-2	Groove	–	–	–	–	–	7.7
		Land	–	–	–	–	–	7.5
	3-3	Groove	–	–	–	–	–	7.7
		Land	–	–	–	–	–	7.5
	3-4	Groove	11.7	6.2	7.6	0.65	0.25	7.7
		Land	12.2	6.5	7.9	0.65	0.25	7.4
	3-5	Groove	–	–	–	–	–	7.6
		Land	–	–	–	–	–	7.4
	3-6	Groove	–	–	–	–	–	7.7
		Land	–	–	–	–	–	7.5
Ex. 2	4-1	Groove	10.3	6.2	7.7	0.75	0.37	7.5
		Land	10.8	6.5	8.1	0.75	0.37	7.2
	4-2	Groove	–	–	–	–	–	7.6
		Land	–	–	–	–	–	7.4
	4-3	Groove	–	–	–	–	–	7.7
		Land	–	–	–	–	–	7.5
	4-4	Groove	10.2	6.2	7.6	0.75	0.35	7.6
		Land	10.6	6.5	7.9	0.75	0.34	7.3
	4-5	Groove	–	–	–	–	–	7.6
		Land	–	–	–	–	–	7.4
	4-6	Groove	–	–	–	–	–	7.7
		Land	–	–	–	–	–	7.4

[0085] At first, as understood from Comparative Example 1 shown in Table 1, the jitter, which is produced by the apparatus A during the recording and reproduction, has approximately the same value as that of the jitter which is produced by the apparatus B during the recording and

reproduction when the recording is performed at the optimum powers with the apparatus A in which Tr and Tf are relatively large, i.e., 2.7 ns and 2.4 ns respectively by using the recording strategy Sb0 obtained by performing the optimization with the apparatus B in which the rising time Tr and the falling time Tf of the laser power are small, i.e., 1.1 ns and 0.9 ns respectively if the clock length is 17.1 ns and the recording linear velocity in the x2 speed recording is 8.2 m/s on condition that the second recording power level P1 is the same as the third power level Pm.

[0086] However, as understood from Comparative Example 2 as well, the jitter, which is produced during the recording and reproduction with the apparatus B, is not more than 8 % of the target, while the jitter, which is produced during the recording and reproduction with the apparatus A, exceeds 9 % which is the upper limit of the standard when the recording is performed at the optimum powers with the apparatus A by using the recording strategy Sb1 obtained by performing the optimization with the apparatus B if the clock length is 6.9 ns and the recording linear velocity in the x5 speed recording is 20.5 m/s on condition that the second recording power level P1 is the same as the third power level Pm. According to this fact, it is understood that the compatibility of the recording cannot be established between the apparatuses in which Tr and Tf are different from each other when the recording linear

velocity is increased. In Comparative Example 1, Pm/Ph = 0.43 to 0.46 is given for the ratio between the first power level Ph and the third power level Pm, and the value of 0 is given for the numerical value (Pm-Pl)/(Ph-Pl) which represents the unsaturation level of the laser power.

[0087] As Example 1, the following is illustrative of the case in which the third power level Pm is changed depending on the recording linear velocity, and the ratio Pm/Ph between the first power level Ph and the third power level Pm is set to 0.65, i.e., Pm/Ph = 0.65. When the recording and reproduction are performed with the apparatus B at the linear velocity of 20.5 m/s by using the recording strategy Sb2 obtained by performing the optimization with the apparatus B on condition that the recording linear velocity in the x5 speed recording is 20.5 m/s, then the value of the jitter, which is obtained in this case, is approximately the same as the value obtained in Comparative Example 2, which is not more than 8 % of the target. The values of the jitter, which are obtained when the data recorded with the apparatus B is reproduced at the linear velocities of 20.5 m/s and 8.2 m/s with the apparatus A, are also approximately the same as those obtained when the reproduction is performed with the apparatus B, which are not more than 8 % of the target. Further, when the recording and reproduction are performed at the optimum powers determined to satisfy Pm/Ph = 0.65 by using the

recording strategy Sb2 at the linear velocity of 20.8 m/s with the apparatus A, the jitter has approximately the same value as that obtained when the recording and reproduction are performed with the apparatus B, which is not more than 8 % of the target. The values of the jitter, which are obtained when the data recorded with the apparatus A is reproduced at the linear velocities of 20.5 m/s and 8.2 m/s with the apparatus B, are also approximately the same as those obtained when the reproduction is performed with the apparatus B, which are not more than 8 % of the target. According to this fact, it is appreciated that the recording compatibility can be established between the apparatuses in which Tr and Tf are different from each other even when the recording linear velocity is increased, by changing the third power level Pm depending on the recording linear velocity and establishing Pm/Ph = 0.65. In Example 1, the value of the numerical value (Pm-P1)/(Ph-P1) for representing the unsaturation level of the laser power is 0.25 to 0.27.

[0088] Further, as Example 2, the following is illustrative of the case in which the third power level Pm is changed depending on the recording linear velocity, and the ratio Pm/Ph between the first power level Ph and the third power level Pm is set to 0.75, i.e., Pm/Ph = 0.75. When the recording and reproduction are performed with the apparatus B at the linear velocity of 20.5 m/s by using the

recording strategy Sb3 obtained by performing the optimization with the apparatus B on condition that the recording linear velocity in the x5 speed recording is 20.5 m/s, then the value of the jitter, which is obtained in this case, is approximately the same as the value obtained in Comparative Example 2, which is not more than 8 % of the target. The values of the jitter, which are obtained when the data recorded with the apparatus B is reproduced at the linear velocities of 20.5 m/s and 8.2 m/s with the apparatus A, are also approximately the same as those obtained when the reproduction is performed with the apparatus B, which are not more than 8 % of the target.

[0089] Further, when the recording and reproduction are performed at the optimum powers determined to satisfy Pm/Ph = 0.75 by using the recording strategy Sb3 at the linear velocity of 20.8 m/s with the apparatus A, the jitter has approximately the same value as that obtained when the recording and reproduction are performed with the apparatus B, which is not more than 8 % of the target. The values of the jitter, which are obtained when the data recorded with the apparatus A is reproduced at the linear velocities of 20.5 m/s and 8.2 m/s with the apparatus B, are also approximately the same as those obtained when the reproduction is performed with the apparatus B, which are not more than 8 % of the target. According to this fact, it is appreciated that the recording compatibility can be

established between the apparatuses in which Tr and Tf are different from each other even when the recording linear velocity is increased, by changing the third power level Pm depending on the recording linear velocity and establishing Pm/Ph = 0.75. In Example 2, the value of the numerical value (Pm-P1)/(Ph-P1) for representing the unsaturation level of the laser power is 0.34 to 0.37.

[0090] As described above, in principle, the determination of the optimum recording power resides in the complicated step of determining the three values of Ph, P1, and Pm. On the contrary, when the value of Ph/Pm is established depending on the recording speed, the value of Pm can be determined from the value of Ph. Therefore, the determination of the optimum recording power can be simplified into the step of determining the two values of Ph and P1.

[0091] As understood from the fact that the values of Ph in Examples 1 and 2 of the present invention are smaller than the value of Ph in Comparative Example 2, it is possible to decrease the maximum level of the recording power when the present invention is used. According to this fact, when the present invention is applied to the information-recording apparatus which has the upper limit of the output value of the laser power, an effect is obtained such that the recording linear velocity and the

data transfer rate can be further enhanced, and the clock length of the recording data can be further shortened.

[0092] Further reference may be made, for example, to the pulse width of the 7T signal after the 3T signal in the recording strategies Sb1, Sb2, and Sb3 used in Examples. The pulse width Tfp of the leading pulse and the pulse width Tlp of the tail pulse shown in Fig. 19 are as follows on the basis of the clock length T. That is, Tfp = 1.75T and Tlp = 0.63T are given in the case of Sb1, Tfp = 2.06T and Tlp = 0.56T are given in the case of Sb2, and Tfp = 2.38T and Tlp = 0.50T are given in the case of Sb3. As described above, the values of Tfp and Tlp are changed in the respective recording strategies. Therefore, the optimization of the recording strategy can be performed in a simplified manner by changing the pulse width Tfp of the leading pulse and the pulse width Tlp of the tail pulse of the recording strategy depending on the recording linear velocity, the third power level Pm, the ratio Pm/Ph between the first power level Ph and the third power level Pm, or the numerical value (Pm-Pl)/(Ph-Pl) for representing the unsaturation level of the laser power. Consequently, it is also possible to simplify the step of optimizing the recording power to be performed with the optimum recording strategy.

[0093] As explained above, according to the present

invention, the optimum recording laser power can be easily established for the information-recording apparatus while considering the influence of the rising time and the falling time of the laser when the linear velocity of the data recording and the data transfer rate are increased. Further, according to the present invention, the recording compatibility can be secured between the information-recording apparatuses in which the linear velocity of the data recording, the data transfer rate, and the rising time and the falling time of the laser are different from each other.

[0094] In Examples of the present invention, the recording compatibility has been verified by using the strategy optimized with the apparatus B in which the rising time and the falling time of the laser are small. However, according to the present invention, it has been successfully confirmed that the recording compatibility is obtained even in the case of the use of a strategy optimized with the apparatus B in which the rising time and the falling time of the laser are large.

[0095] The expression of "laser beam" is adopted in this specification. However, the effect of the present invention is obtained provided that any energy beam is used, which makes it possible to change the state of the information-recording portion of the information-recording

medium according to the present invention. Therefore, the effect of the present invention is not lost even when an energy beam such as an electron beam is used.

[0096] In Examples of the present invention, the red laser having the wavelength of 655 nm is used. However, the present invention does not specifically depend on the wavelength of the laser. The present invention also exhibits the effect on the information-recording apparatus to use any laser having a relatively short wavelength including, for example, blue lasers and ultraviolet lasers, as well as on the information-recording medium to be used therefor.

[0097] In Examples of the present invention, the phase-change disk is used for the information-recording medium. However, the present invention is applicable to any information-recording medium provided that information is recorded thereon by being irradiated with the energy beam. Therefore, the present invention is also applicable to any information-recording medium other than the disk-shaped information-recording medium, including, for example, optical cards, especially irrelevant to the material and the structure for constructing the information-recording medium and the shape of the information-recording medium.

[0098]

[EFFECTS OF THE INVENTION]

The present invention resides in the information-recording method including the steps of relatively scanning the information-recording medium and the laser beam at the linear velocity within the certain range and changing the state of the information-recording portion of the information-recording medium to record information thereby by using the pulse sequence composed of the plurality of pulses with the power level of the first power level Ph while power-modulating the laser power of the laser beam to at least the first power level Ph and the second power level Pl which is lower than the first power level, wherein the power level, which is provided between the plurality of pulses, is the third power level Pm between the first power level Ph and the second power level Pl, and the third power level Pm is changed in response to the linear velocity. Accordingly, it is possible to secure the compatibility of the recording between the information-recording apparatuses in which the linear velocity during the recording and the rising time and the falling time of the laser power are different from each other.

[0099] Further, the recording power can be optimized with ease by increasing Pm in proportion to the linear velocity.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[FIG. 1] Fig. 1 schematically shows the fact that the rising time of the laser power can be calculated with a

cosine curve.

[FIG. 2] Fig. 2 schematically shows the fact that the falling time of the laser power can be calculated with a cosine curve.

[FIG. 3] Fig. 3 schematically shows the rising time Tr and the falling time Tf of the laser power in the present invention.

[FIG. 4] Fig. 4 shows a result of calculation for a recording pulse waveform in which the laser power is in the saturated state.

[FIG. 5] Fig. 5 shows a result of calculation for a recording pulse waveform in which the laser power is in the unsaturated state.

[FIG. 6] Fig. 6 shows the change of Ph depending on Tr, Tf and the recording speed on account of the unsaturation phenomenon of the laser power assuming that the vertical axis represents the power level Ph and the horizontal axis represents the rising time Tr and the falling time Tf of the laser power.

[FIG. 7] Fig. 7 shows the change of Pm depending on Tr, Tf and the recording speed on account of the unsaturation phenomenon of the laser power assuming that the vertical axis represents the power level Pm and the horizontal axis represents the rising time Tr and the falling time Tf of the laser power.

[FIG. 8] Fig. 8 shows the change of Ph depending on

the recording speed and the rising time Tr and the falling time Tf of the laser power on account of the unsaturation phenomenon of the laser power assuming that the vertical axis represents the power level Ph and the horizontal axis represents the recording speed.

[FIG. 9] Fig. 9 shows the change of Pm depending on the recording speed and the rising time Tr and the falling time Tf of the laser power on account of the unsaturation phenomenon of the laser power assuming that the vertical axis represents the power level Pm and the horizontal axis represents the recording speed.

[FIG. 10] Fig. 10 shows the nonlinear change of the relationship between the unsaturation level [(Pm-P1)/(Ph-P1)] of the laser power and the recording speed depending on the rising time Tr and the falling time Tf of the laser power on account of the unsaturation phenomenon of the laser power.

[FIG. 11] Fig. 11 shows the setting to provide the linear relationship by changing [(Pm-P1)/(Ph-P1)] depending on the recording speed so that the relationship between the unsaturation level [(Pm-P1)/(Ph-P1)] of the laser power and the recording speed as shown in Fig. 10 is not affected by the unsaturation phenomenon of the laser power.

[FIG. 12] Fig. 12 shows the disappearance of the change of the power level Ph depending on the rising time Tr and the falling time Tf of the laser power as a result

of the provision of the relationship of the setting as shown in Fig. 11 between the unsaturation level [(Pm-P1)/(Ph-P1)] of the laser power and the recording speed.

[FIG. 13] Fig. 13 shows the disappearance of the change of the power level Pm depending on the rising time Tr and the falling time Tf of the laser power as a result of the provision of the relationship of the setting as shown in Fig. 11 between the unsaturation level [(Pm-P1)/(Ph-P1)] of the laser power and the recording speed.

[FIG. 14] Fig. 14 shows the power level Ph which does not depend on the rising time Tr and the falling time Tf of the laser power and which is definitely determinable by the recording speed as a result of the provision of the relationship of the setting as shown in Fig. 11 between the unsaturation level [(Pm-P1)/(Ph-P1)] of the laser power and the recording speed.

[FIG. 15] Fig. 15 shows the power level Pm which does not depend on the rising time Tr and the falling time Tf of the laser power and which is definitely determinable by the recording speed as a result of the provision of the relationship of the setting as shown in Fig. 11 between the unsaturation level [(Pm-P1)/(Ph-P1)] of the laser power and the recording speed.

[FIG. 16] Fig. 16 shows a case of the setting to provide the linear relationship by changing Pm/Ph depending on the recording speed so that the relationship between

Pm/Ph and the recording speed is not affected by the unsaturation phenomenon of the laser power by substituting the vertical axis shown in Fig. 11 with the ratio Pm/Ph of the laser power level.

[FIG. 17] Fig. 17 shows a case of the setting to provide the linear relationship by changing (Pm/Ph)/(Pmx2/Phx2) depending on the recording speed so that the relationship between (Pm/Ph)/(Pmx2/Phx2) and the recording speed is not affected by the unsaturation phenomenon of the laser power by substituting the vertical axis shown in Fig. 16 with the value (Pm/Ph)/(Pmx2/Phx2) obtained by normalizing the ratio Pm/Ph of the laser power level with the ratio Phx2/Pmx2 of the laser power level in the x2 speed recording.

[FIG. 18] Fig. 18 schematically shows an information-recording and reproducing apparatus for optical recording media used to investigate the recording and reproduction characteristics in embodiments of the present invention.

[FIG. 19] Fig. 19 explains the strategy of recording pulses used to investigate the recording and reproduction characteristics in embodiments of the present invention.

[EXPLANATION OF REFERENCE NUMERALS]

18-1 information-recording medium

18-2 motor

18-3 optical head

18-4 preamplifier circuit

18-5	recording waveform-generating circuit
18-6	laser-driving circuit
18-78-16	modulator
18-8	L/G servo circuit
18-98-16	demodulator

[TITLE OF THE DOCUMENT] Abstract

[ABSTRACT]

[TASK] To provide an information-recording method with which an optimum recording power can be easily obtained and the recording compatibility can be secured for information-recording apparatuses having mutually different recording liner velocities and mutually different rising times and falling times of laser powers, and to provide an information-recording medium to be used for the method.

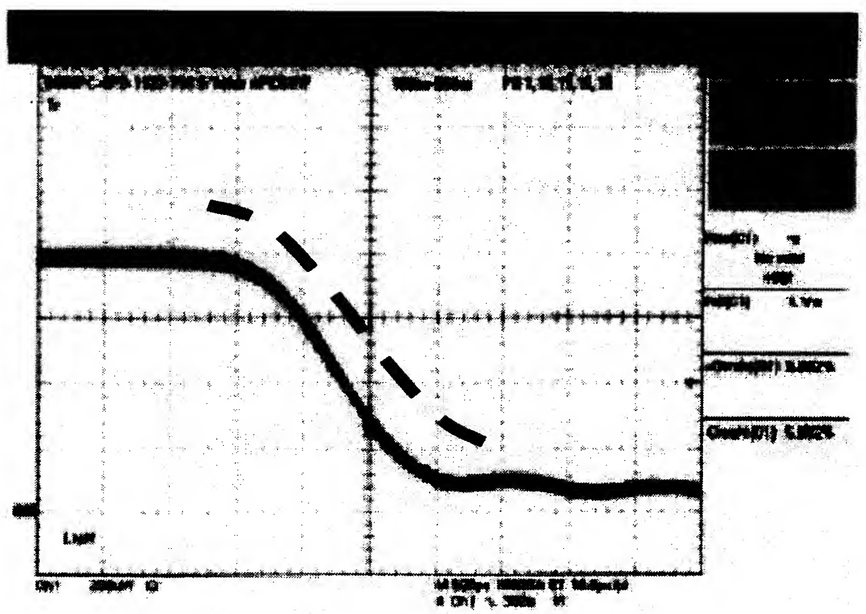
[MEANS TO SOLVE THE TASK] There is provided an information-recording method for recording information on an information-recording medium by scanning a laser beam at a linear velocity in a predetermined range relative to the information-recording medium and changing a state of a portion, of the information-recording medium, on which the information is to be recorded, by a laser power of the laser beam with a pulse sequence including a plurality of pulses which are modulated between at least a first power level Ph and a second power level Pl lower than the first power level, and of which power level is the first power level Ph. In the method, the power level between the pulses is a third power level Pm intermediate between the first power level Ph and the second power level Pl, and the third power level Pm is changed in response to the linear velocity.

[SELECTED DRAWING] Fig. 11

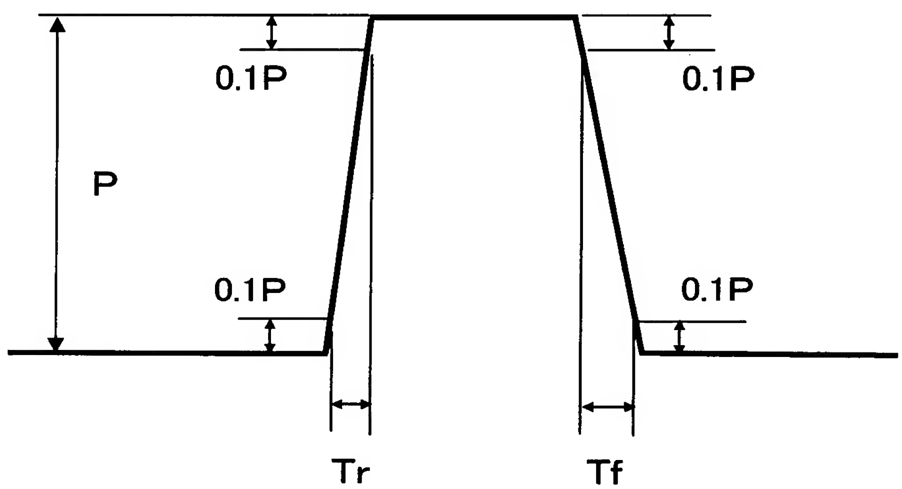
[Title of the document] DRAWING

[FIG. 1]

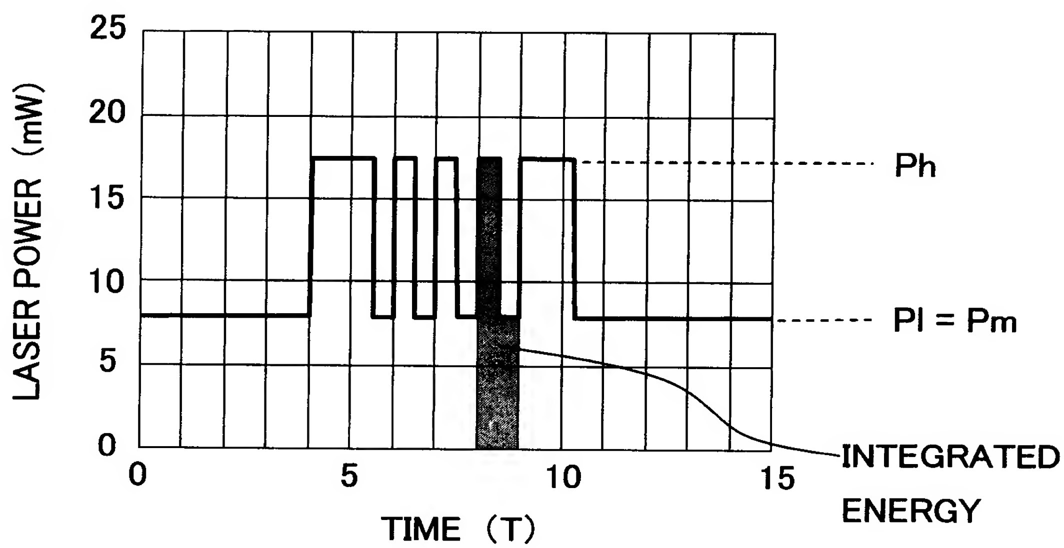
[FIG. 2]



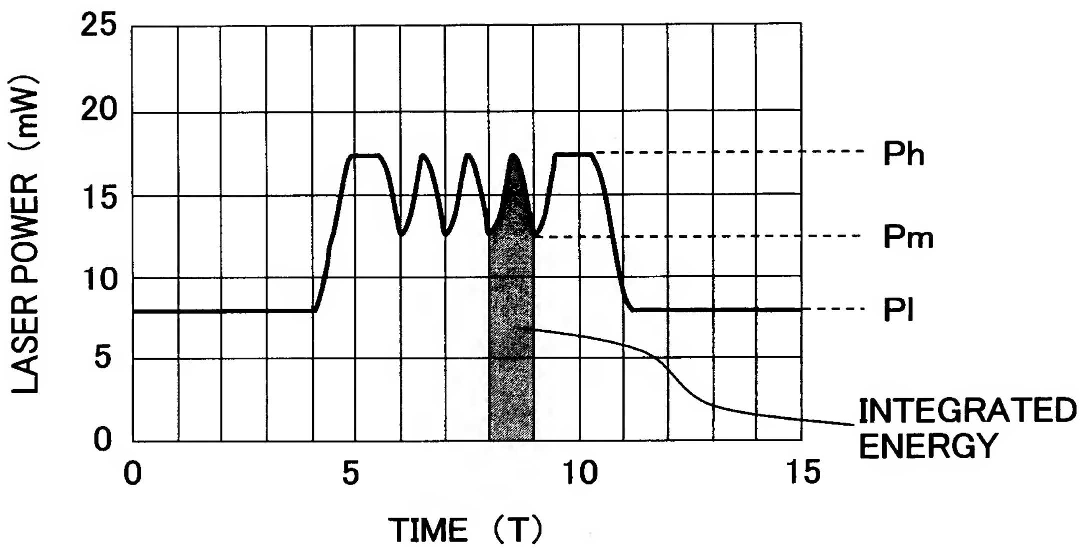
[FIG. 3]


0.1P
0.1P
P
0.1P
0.1P
Tr
Tf

[FIG. 4]

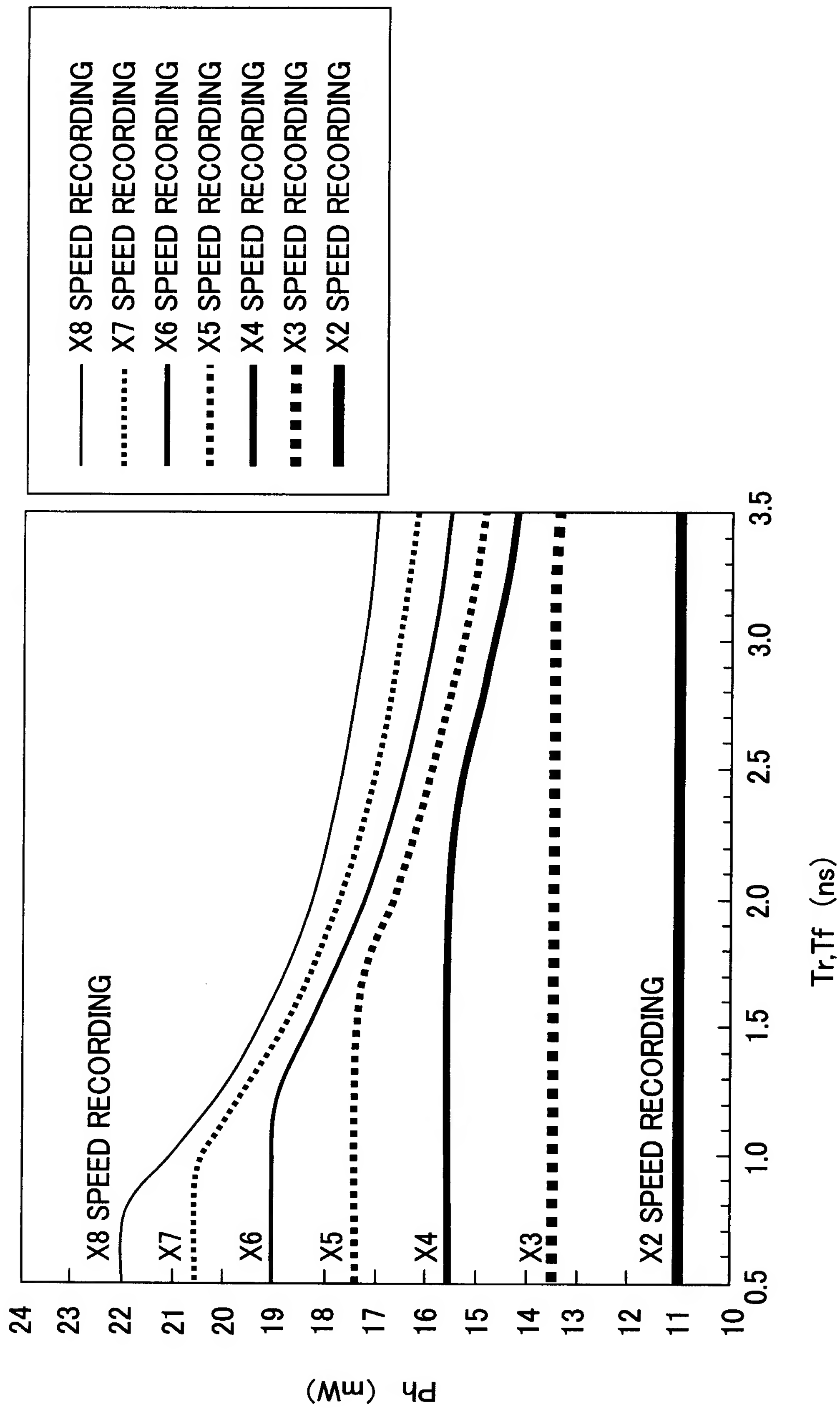

25
20
15
10
5
0
LASER POWER (mW)
0
5
10
15
TIME (T)
Ph
Pl = Pm
INTEGRATED ENERGY

[FIG. 5]

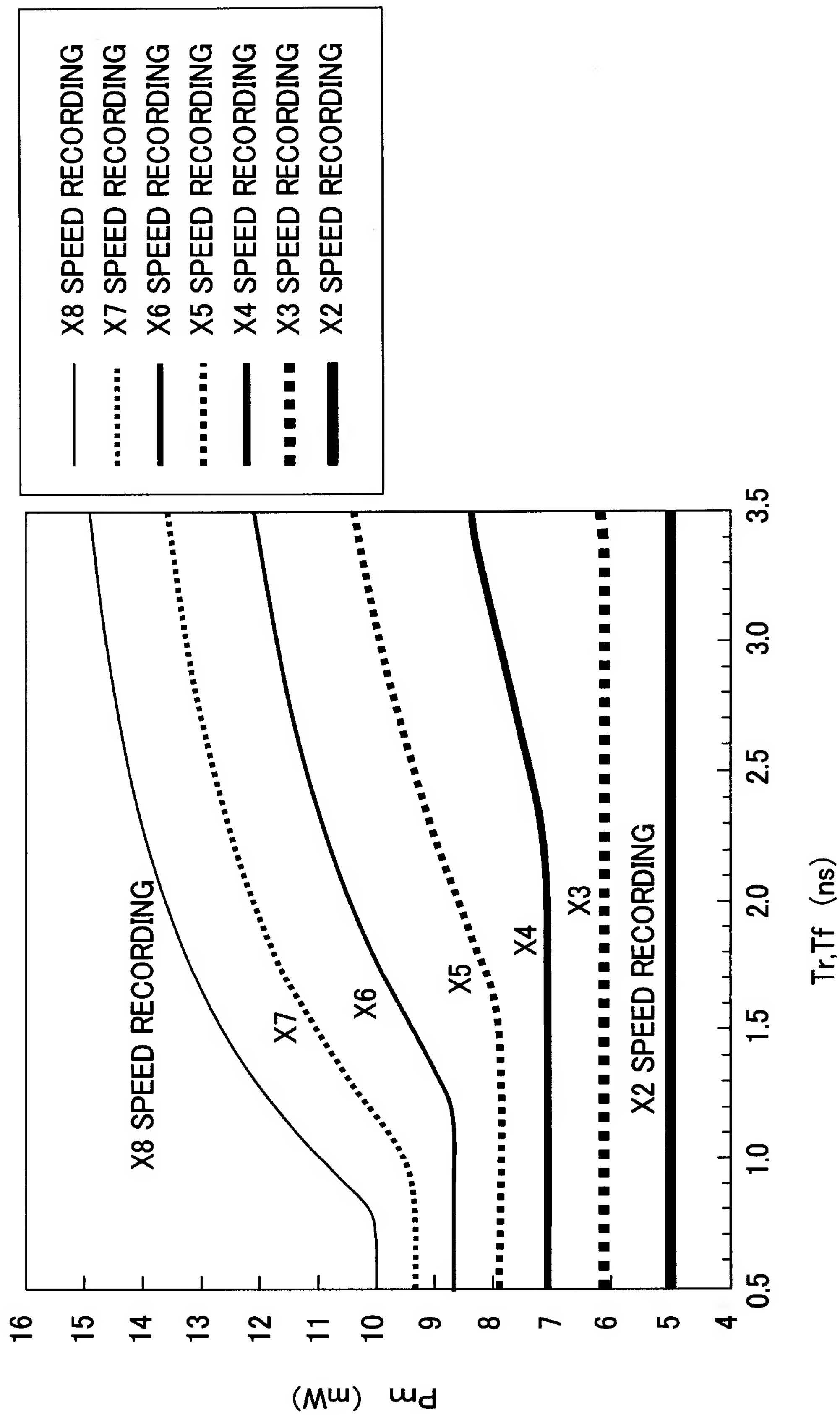


25
20
15
10
5
0
LASER POWER (mW)
0
5
10
15
TIME (T)
Ph
Pm
Pl
INTEGRATED ENERGY

[FIG. 6]

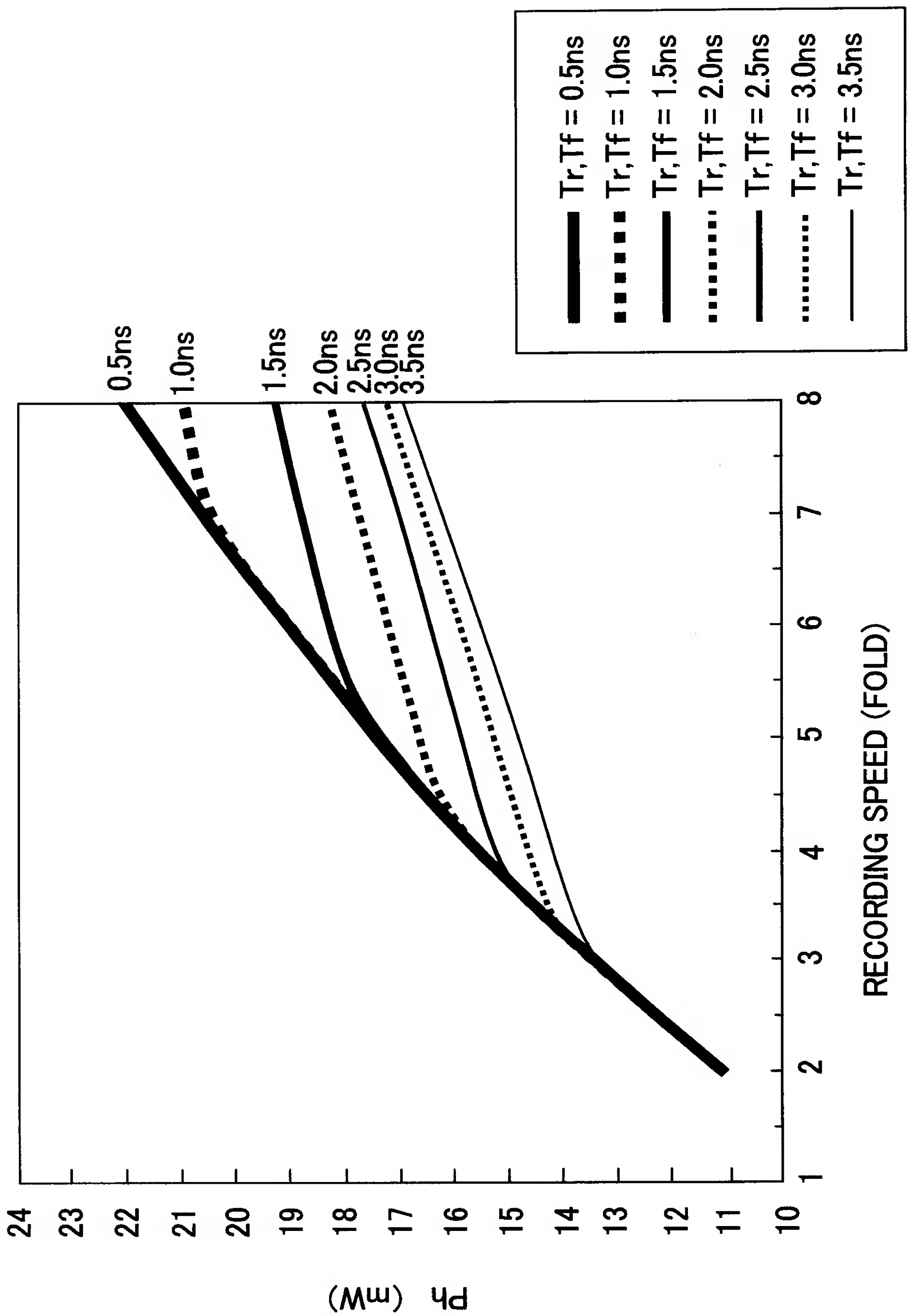

X8 SPEED RECORDING
X7 SPEED RECORDING
X6 SPEED RECORDING
X5 SPEED RECORDING
X4 SPEED RECORDING
X3 SPEED RECORDING
X2 SPEED RECORDING
X8 SPEED RECORDING
X7
X6
X5
X4
X3
X2 SPEED RECORDING
Ph (mW)
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Tr,Tf (ns)

[FIG. 7]



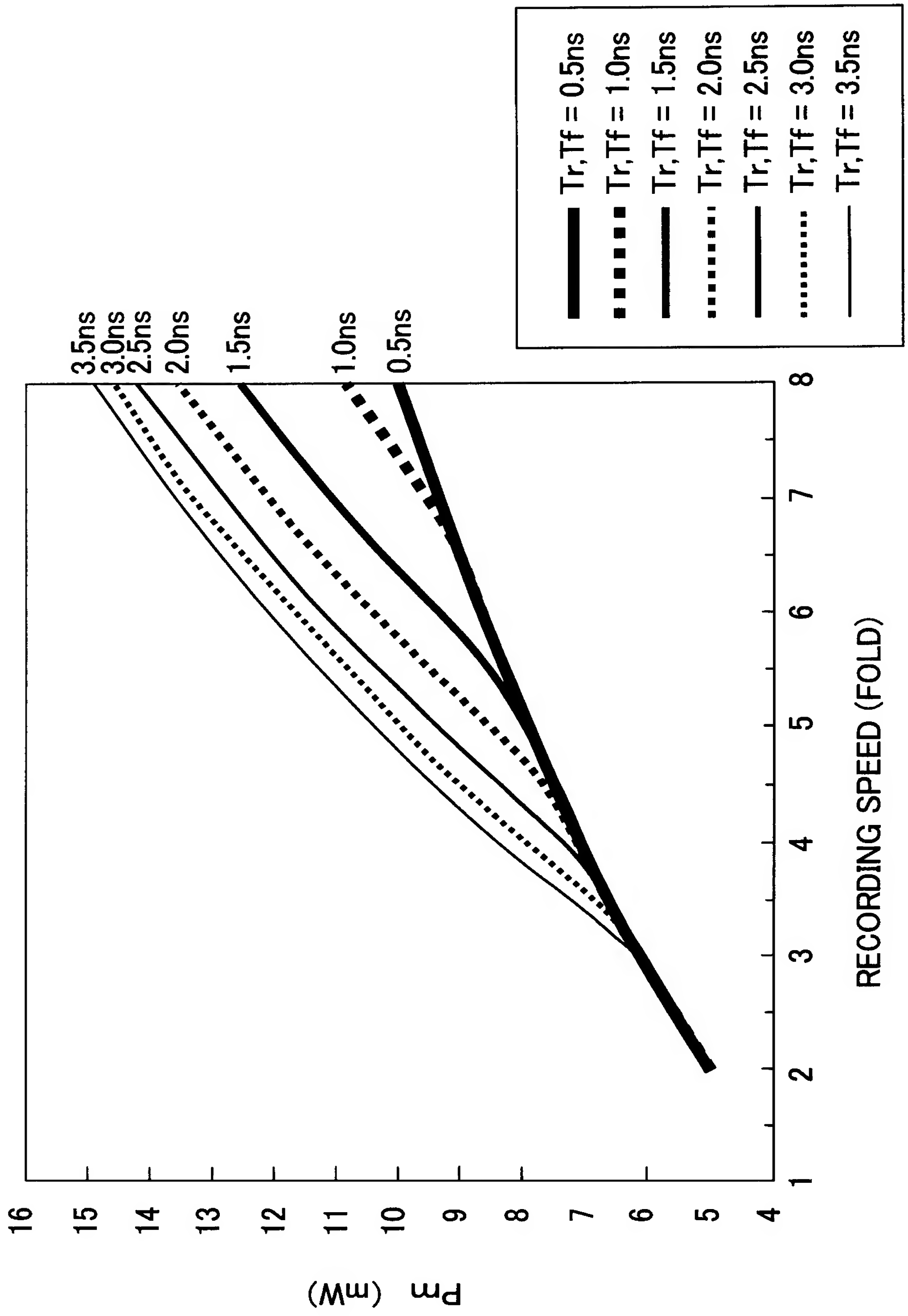
X8 SPEED RECORDING
X7 SPEED RECORDING
X6 SPEED RECORDING
X5 SPEED RECORDING
X4 SPEED RECORDING
X3 SPEED RECORDING
X2 SPEED RECORDING
X8 SPEED RECORDING
X7
X6
X5
X4
X3
X2 SPEED RECORDING
Pm (mW)
16
15
14
13
12
11
10
9
8
7
6
5
4
Tr,Tf (ns)
0.5
1.0
1.5
2.0
2.5
3.0
3.5

[FIG. 8]



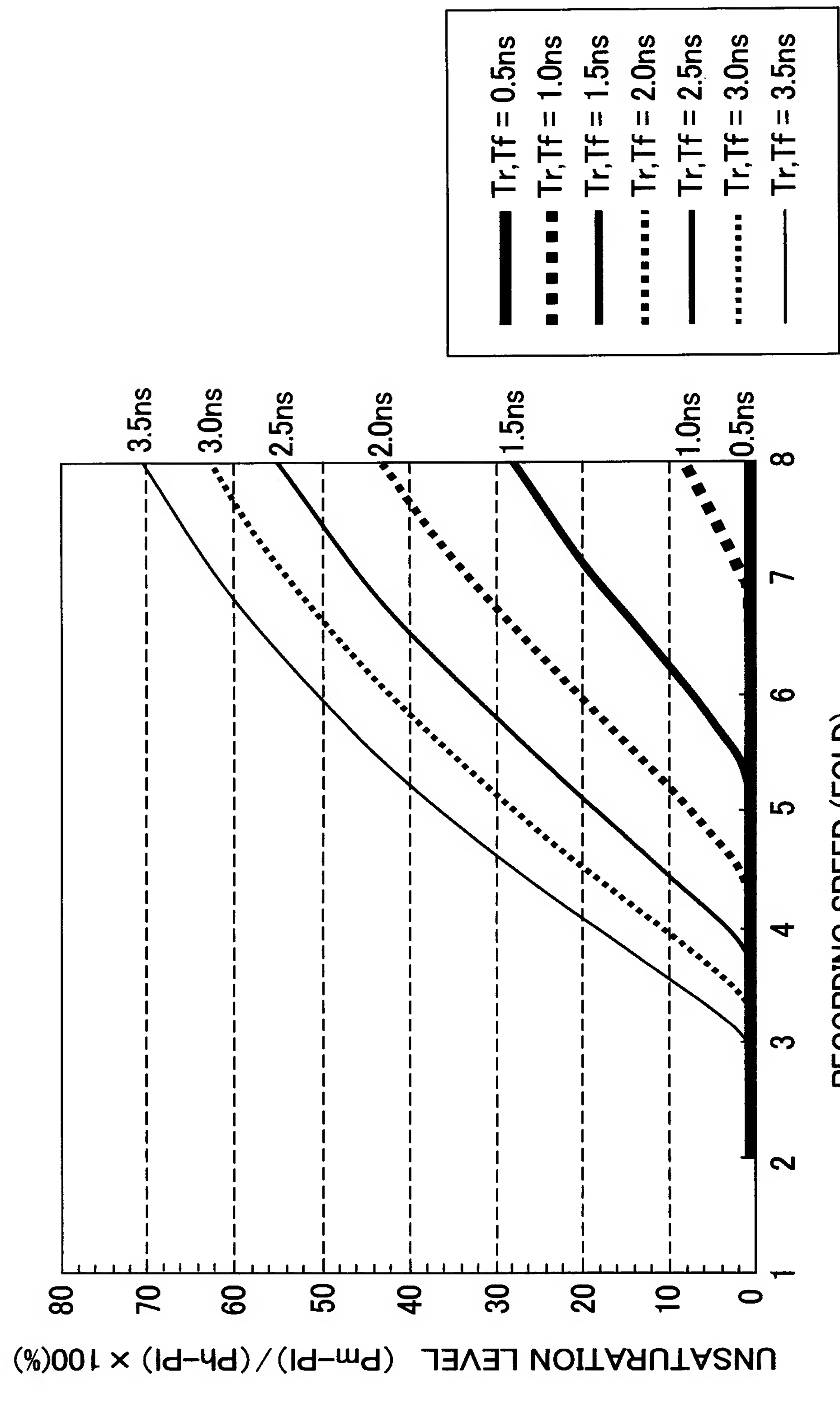
Ph (mW)
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
1
2
3
4
5
6
7
8
RECORDING SPEED (FOLD)
0.5ns
1.0ns
1.5ns
2.0ns
2.5ns
3.0ns
3.5ns
Tr,Tf = 0.5ns
Tr,Tf = 1.0ns
Tr,Tf = 1.5ns
Tr,Tf = 2.0ns
Tr,Tf = 2.5ns
Tr,Tf = 3.0ns
Tr,Tf = 3.5ns

[FIG. 9]



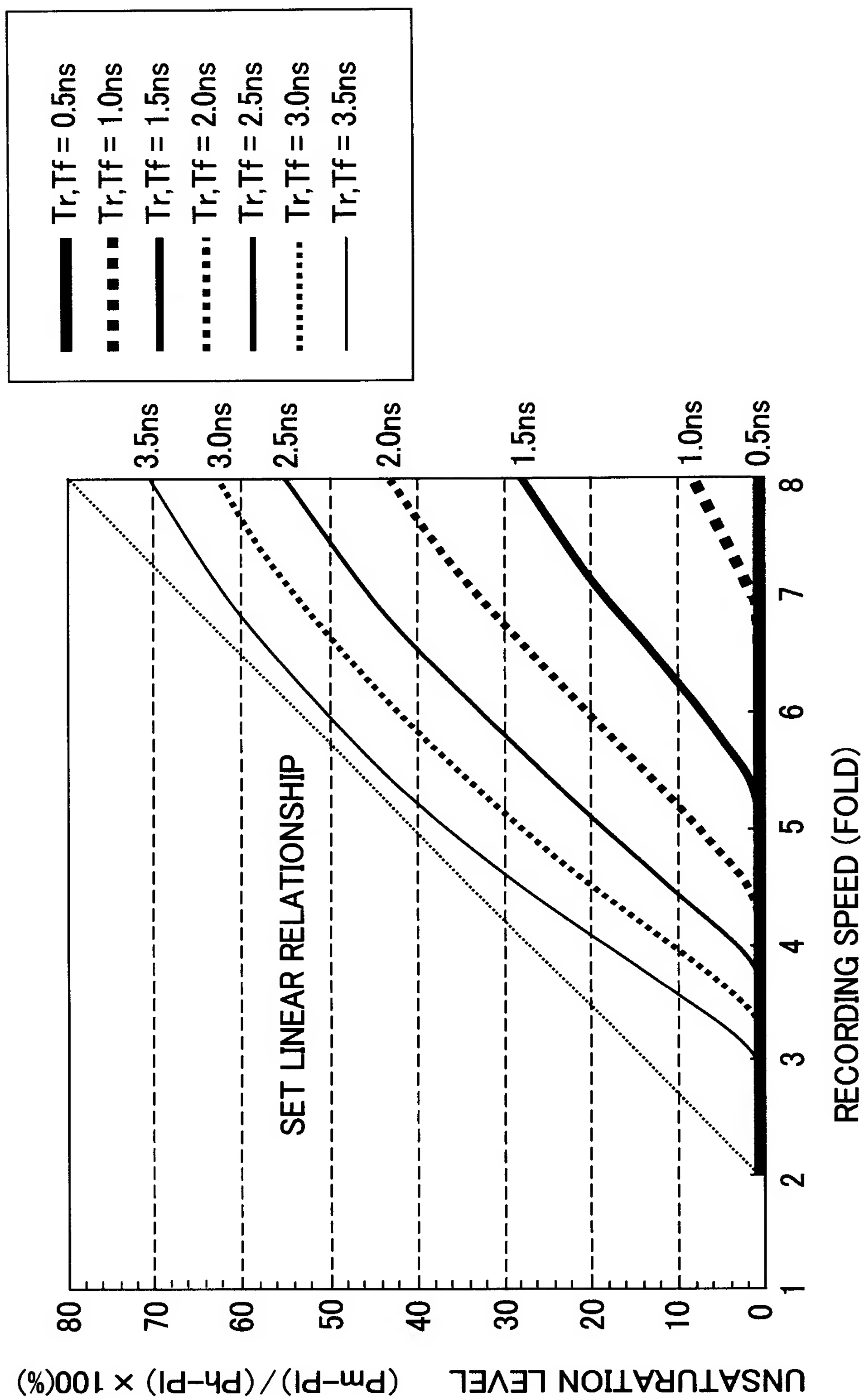
Pm (mW)
4
5
6
7
8
9
10
11
12
13
14
15
16
RECORDING SPEED (FOLD)
1
2
3
4
5
6
7
8
3.5ns
3.0ns
2.5ns
2.0ns
1.5ns
1.0ns
0.5ns
Tr,Tf = 0.5ns
Tr,Tf = 1.0ns
Tr,Tf = 1.5ns
Tr,Tf = 2.0ns
Tr,Tf = 2.5ns
Tr,Tf = 3.0ns
Tr,Tf = 3.5ns

[FIG. 10]



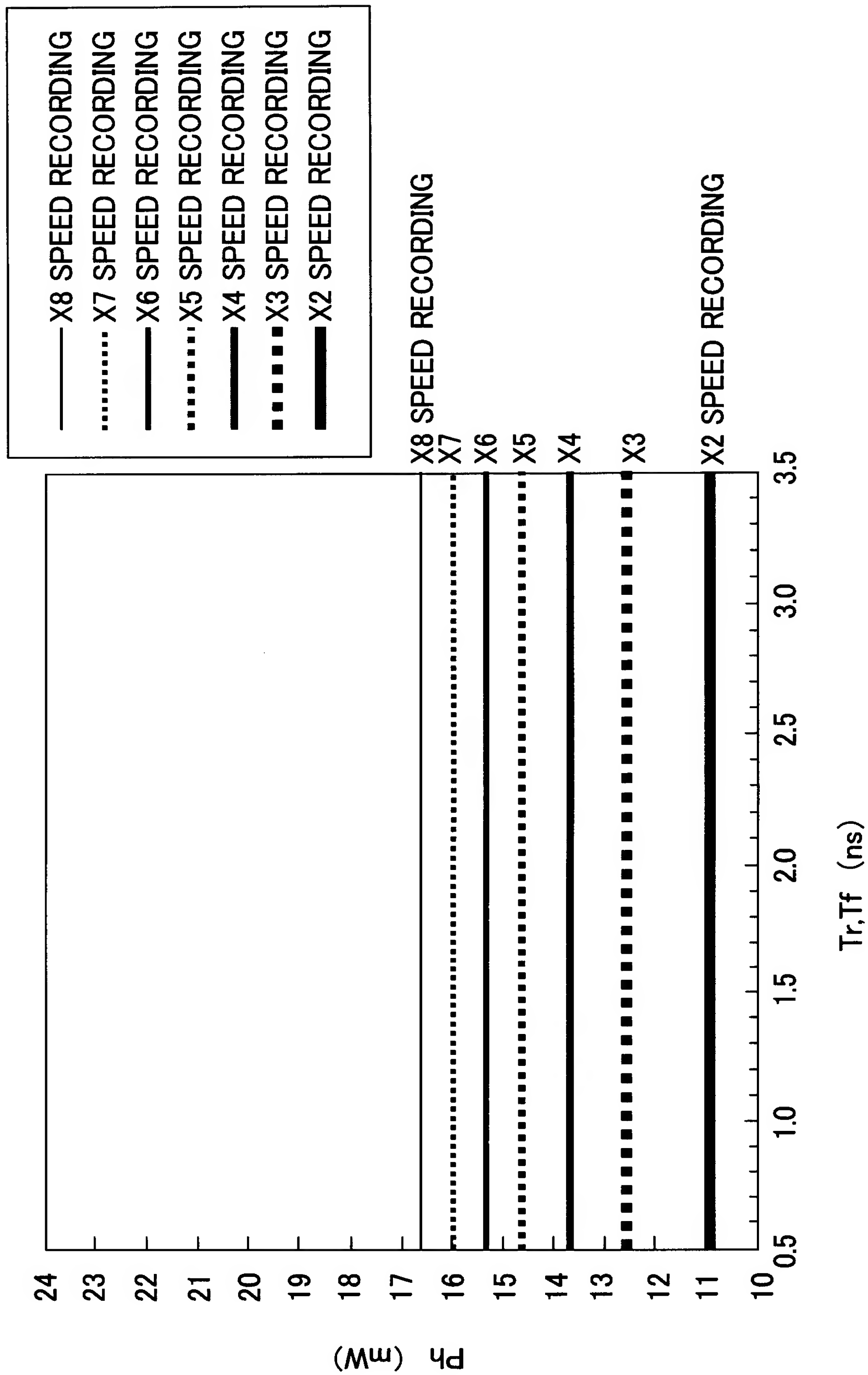
UNSATURATION LEVEL (Pm−Pl)/(Ph−Pl) × 100(%)
RECORDING SPEED (FOLD)
0
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
8
3.5ns
3.0ns
2.5ns
2.0ns
1.5ns
1.0ns
0.5ns
Tr,Tf = 0.5ns
Tr,Tf = 1.0ns
Tr,Tf = 1.5ns
Tr,Tf = 2.0ns
Tr,Tf = 2.5ns
Tr,Tf = 3.0ns
Tr,Tf = 3.5ns

[FIG. 11]

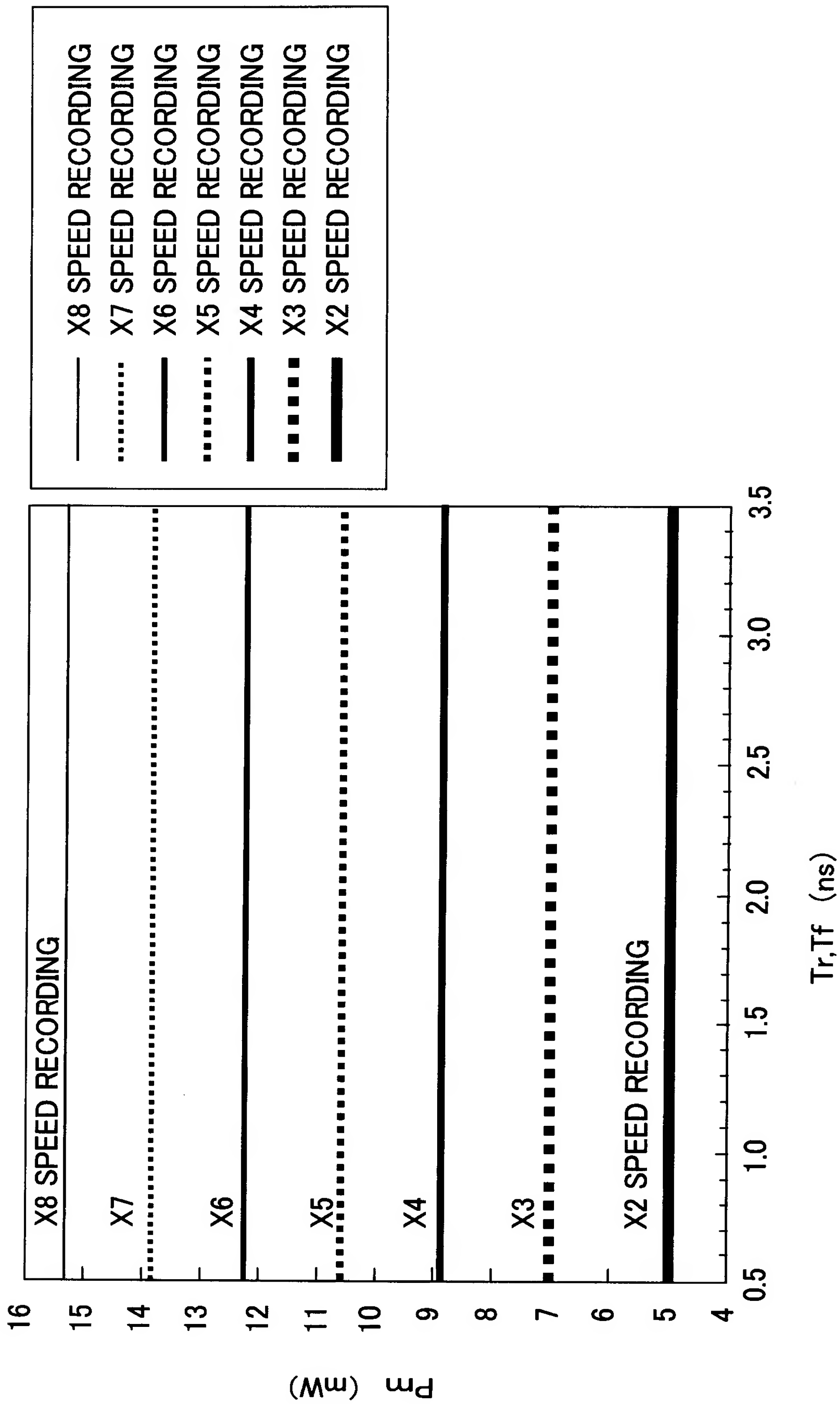


Tr,Tf = 0.5ns
Tr,Tf = 1.0ns
Tr,Tf = 1.5ns
Tr,Tf = 2.0ns
Tr,Tf = 2.5ns
Tr,Tf = 3.0ns
Tr,Tf = 3.5ns
3.5ns
3.0ns
2.5ns
2.0ns
1.5ns
1.0ns
0.5ns
SET LINEAR RELATIONSHIP
UNSATURATION LEVEL
(Pm−Pl)/(Ph−Pl) × 100(%)
RECORDING SPEED (FOLD)
0
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
8

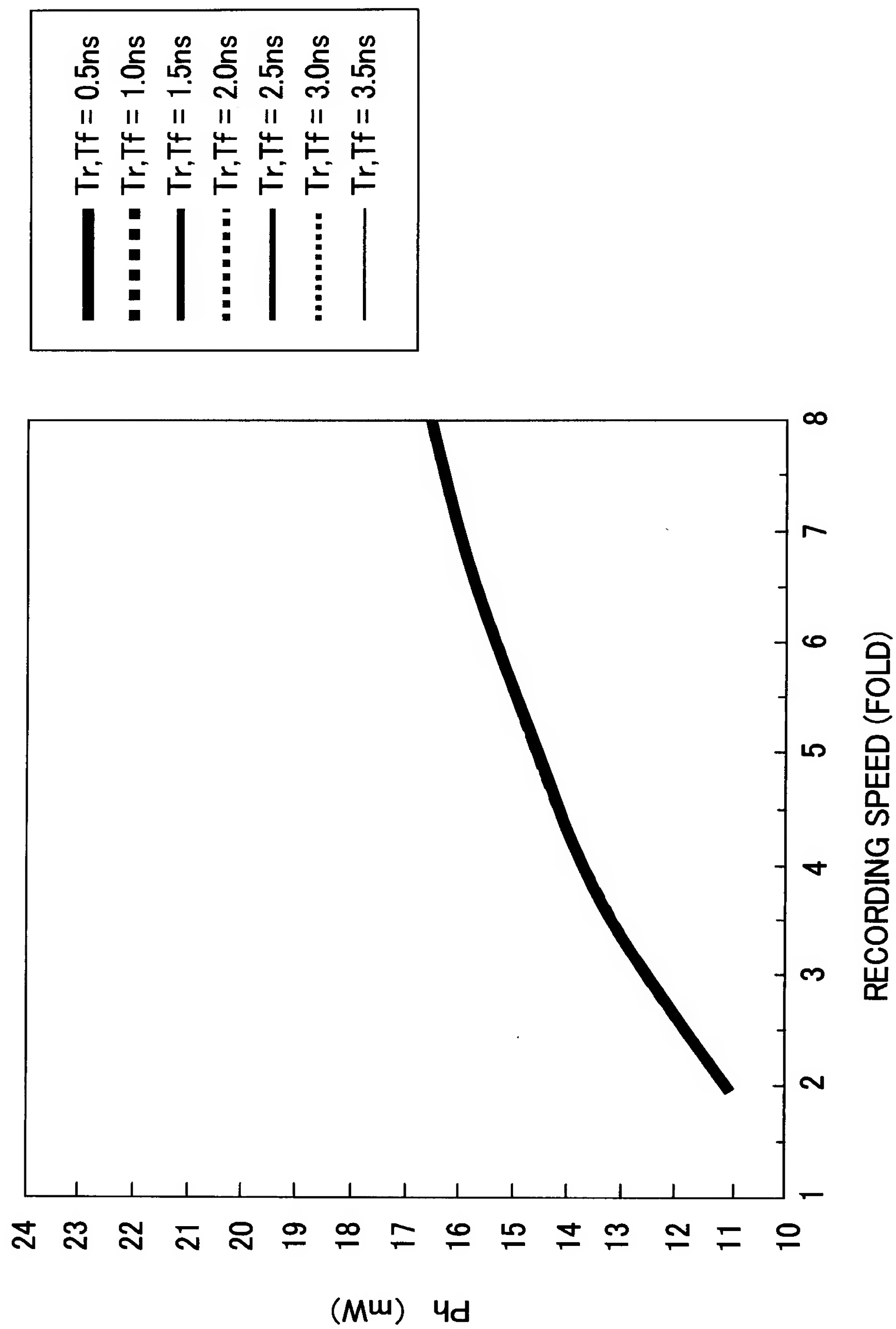
[FIG. 12]


X8 SPEED RECORDING
X7 SPEED RECORDING
X6 SPEED RECORDING
X5 SPEED RECORDING
X4 SPEED RECORDING
X3 SPEED RECORDING
X2 SPEED RECORDING
X8 SPEED RECORDING
X7
X6
X5
X4
X3
X2 SPEED RECORDING
Ph (mW)
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Tr,Tf (ns)

[FIG. 13]

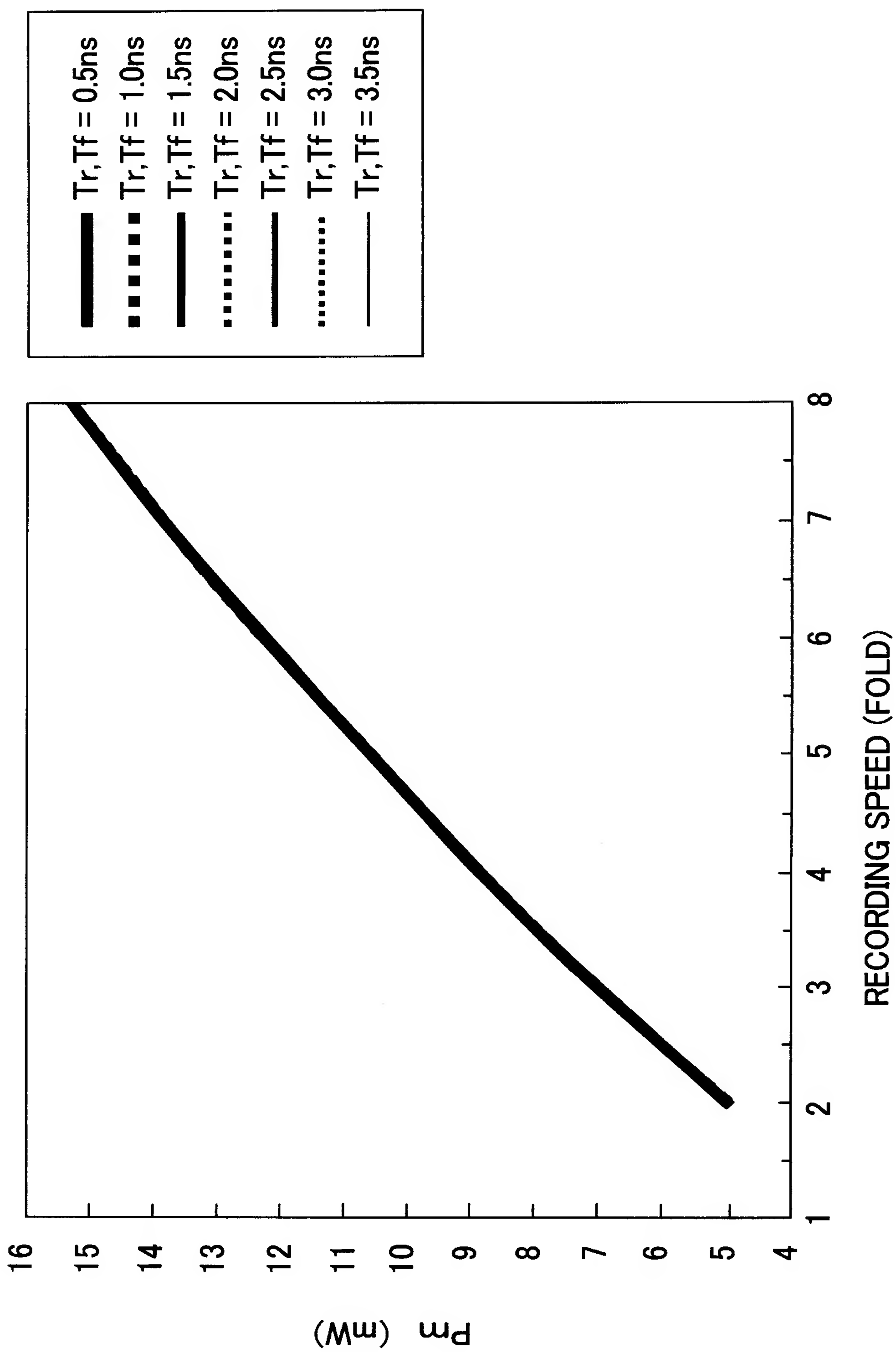

X8 SPEED RECORDING
X7 SPEED RECORDING
X6 SPEED RECORDING
X5 SPEED RECORDING
X4 SPEED RECORDING
X3 SPEED RECORDING
X2 SPEED RECORDING
X8 SPEED RECORDING
X7
X6
X5
X4
X3
X2 SPEED RECORDING
Pm (mW)
16
15
14
13
12
11
10
9
8
7
6
5
4
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Tr,Tf (ns)

[FIG. 14]

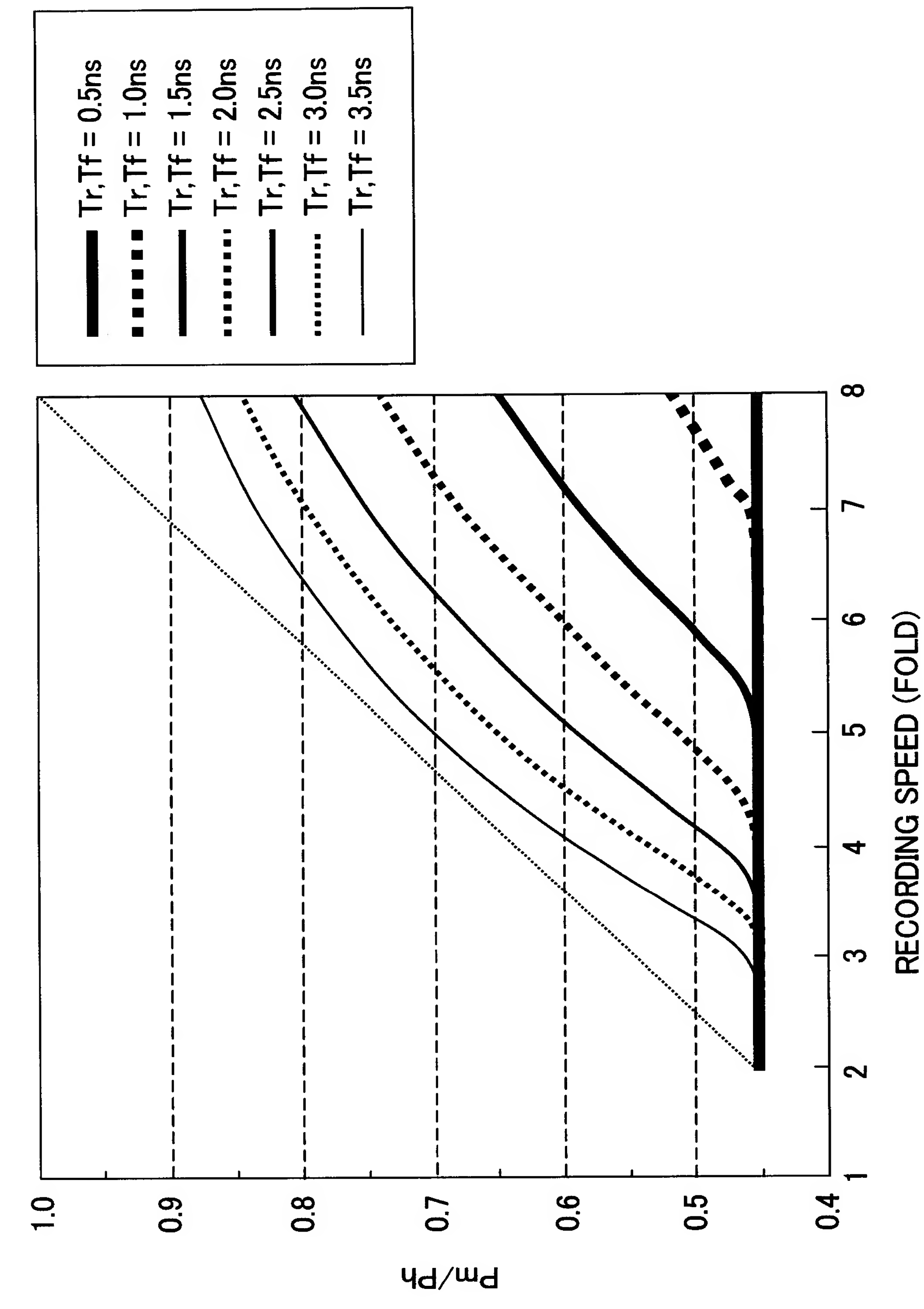


Tr,Tf = 0.5ns
Tr,Tf = 1.0ns
Tr,Tf = 1.5ns
Tr,Tf = 2.0ns
Tr,Tf = 2.5ns
Tr,Tf = 3.0ns
Tr,Tf = 3.5ns
Ph (mW)
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
1
2
3
4
5
6
7
8
RECORDING SPEED (FOLD)

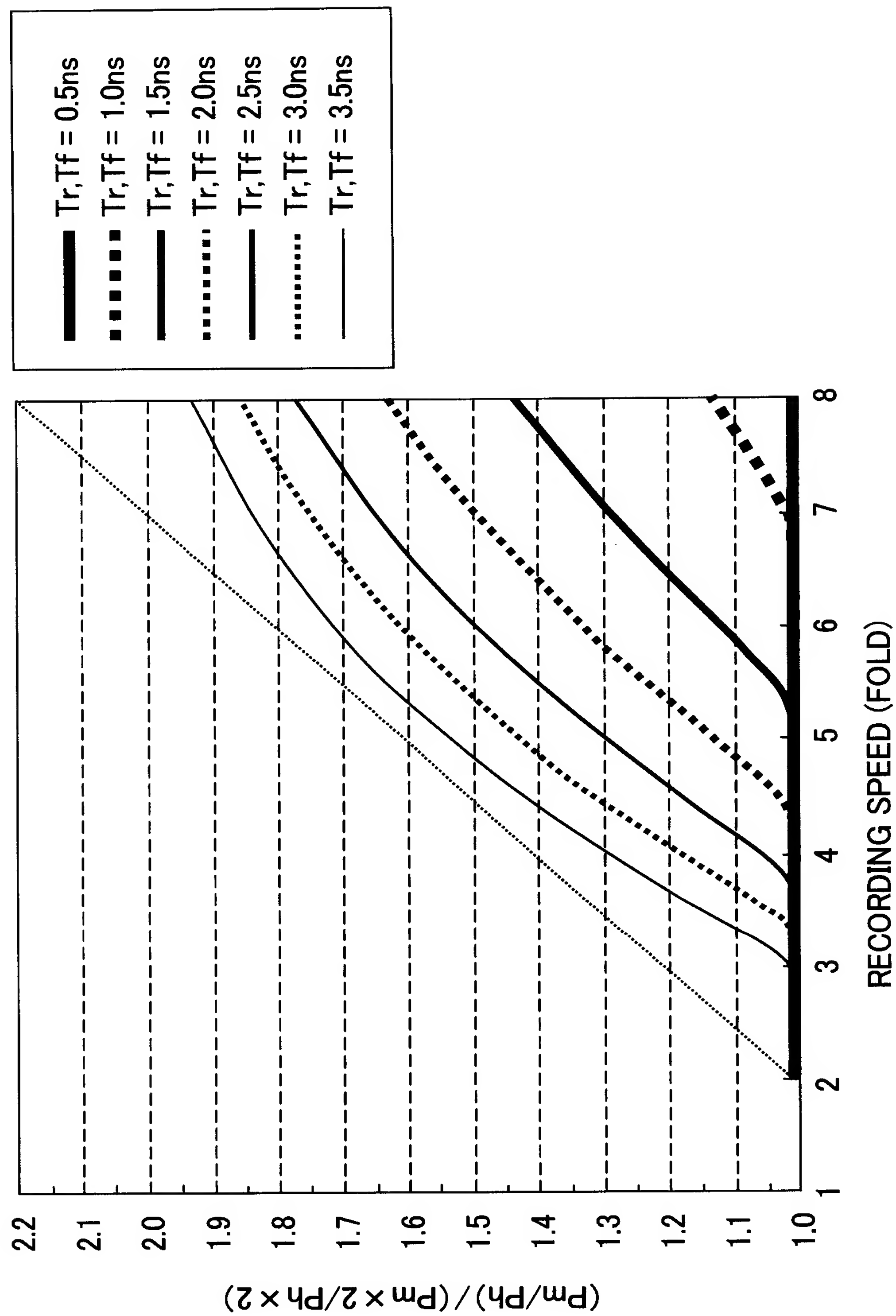
[FIG. 15]


Tr,Tf = 0.5ns
Tr,Tf = 1.0ns
Tr,Tf = 1.5ns
Tr,Tf = 2.0ns
Tr,Tf = 2.5ns
Tr,Tf = 3.0ns
Tr,Tf = 3.5ns
Pm (mW)
16
15
14
13
12
11
10
9
8
7
6
5
4
1
2
3
4
5
6
7
8
RECORDING SPEED (FOLD)

[FIG. 16]

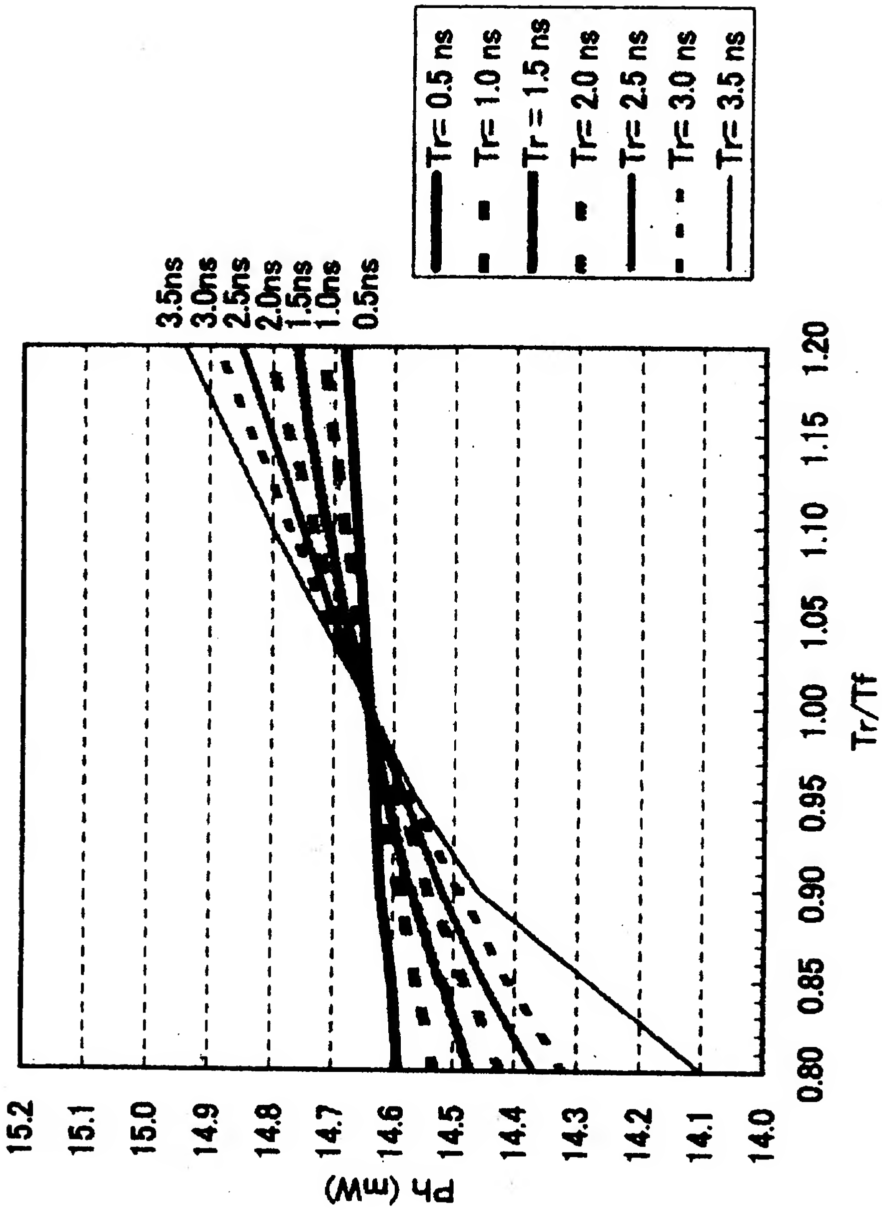

Tr,Tf = 0.5ns
Tr,Tf = 1.0ns
Tr,Tf = 1.5ns
Tr,Tf = 2.0ns
Tr,Tf = 2.5ns
Tr,Tf = 3.0ns
Tr,Tf = 3.5ns
Pm/Ph
1.0
0.9
0.8
0.7
0.6
0.5
0.4
1
2
3
4
5
6
7
8
RECORDING SPEED (FOLD)

[FIG. 17]



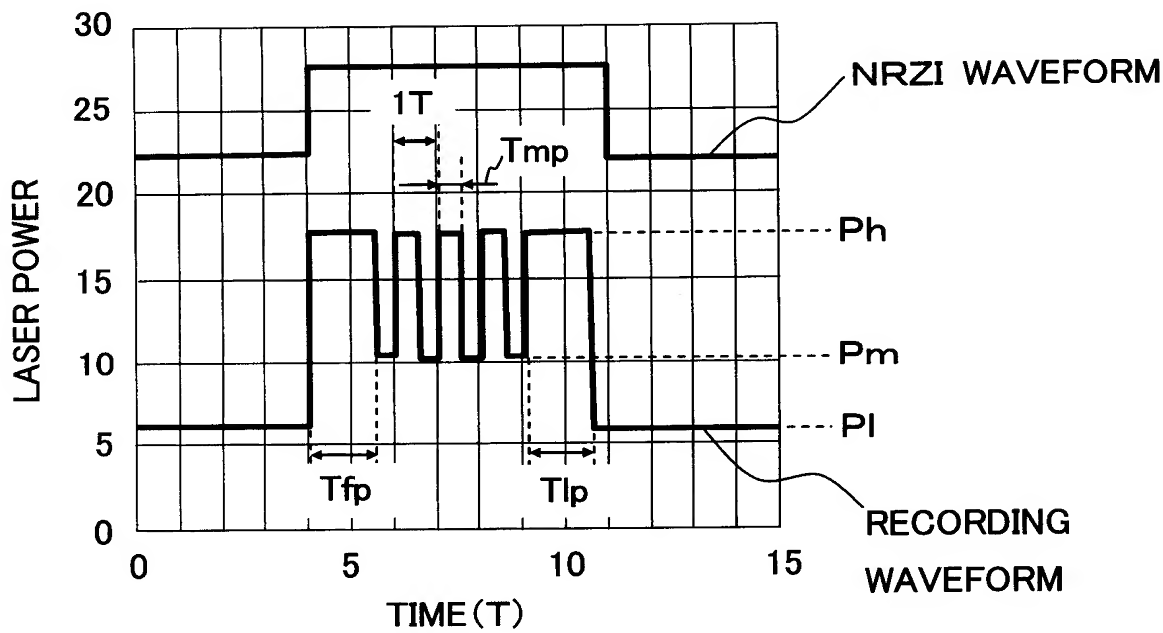
Tr,Tf = 0.5ns
Tr,Tf = 1.0ns
Tr,Tf = 1.5ns
Tr,Tf = 2.0ns
Tr,Tf = 2.5ns
Tr,Tf = 3.0ns
Tr,Tf = 3.5ns
(Pm/Ph) / (Pm × 2/Ph × 2)
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
1
2
3
4
5
6
7
8
RECORDING SPEED (FOLD)

[FIG. 18]



Ph (mW)
15.2
15.1
15.0
14.9
14.8
14.7
14.6
14.5
14.4
14.3
14.2
14.1
14.0
0.80
0.85
0.90
0.95
1.00
1.05
1.10
1.15
1.20
Tr/Tf
3.5ns
3.0ns
2.5ns
2.0ns
1.5ns
1.0ns
0.5ns
Tr= 0.5 ns
Tr= 1.0 ns
Tr = 1.5 ns
Tr= 2.0 ns
Tr= 2.5 ns
Tr= 3.0 ns
Tr= 3.5 ns

[FIG. 19]



30
25
20
15
10
5
0
LASER POWER
0
5
10
15
TIME (T)
1T
Tmp
Tfp
Tlp
NRZI WAVEFORM
Ph
Pm
Pl
RECORDING WAVEFORM